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FOR
TESTING MATERIALS

ORGANIZED IN 1898
INCORPORATED IN 1902

PROCEEDINGS
OF THE
THIRTY-FIRST ANNUAL MEETING

Held at Atlantic City, New Jersey
June 25-29, 1928

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PART I. COMMITTEE REPORTS
NEW AND REVISED TENTATIVE STANDARDS

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American Society for Testing Materials

ORGANIZED IN 1898
INCORPORATED IN 1902

PROCEEDINGS

PART I

The Society is not responsible, as a body, for the statements and opinions advanced in this publication.

SUMMARY OF THE PROCEEDINGS OF THE THIRTY-FIRST ANNUAL MEETING

Atlantic City, N. J., June 25–29, 1928

The Thirty-first Annual Meeting of the American Society for Testing Materials was held at Chalfonte-Haddon Hall, Atlantic City, N. J., June 25–29, 1928. The following is an analysis of the attendance at the meeting: Members in attendance or represented, 809; guests, 93; total, 902; ladies, 286. The corresponding statistics for the Thirtieth Annual Meeting are: Members in attendance or represented, 568; guests, 68; total, 636; ladies, 93.

First Session—Tuesday, June 26, 2 p. m.

Opening General Session

President H. F. Moore in the chair.

The President in opening the annual meeting gave his impressions gained in the past few years of the progress of the Society's work and his view of some of the problems which face it—problems having to do with the proper functioning of committees with the present widespread and large Society membership. He referred to these problems not in any sense in a discouraging way but with the assurance that the Society had work before it for the next fifty years and that the work would be well done and well worth the doing.

The minutes of the Thirtieth Annual Meeting were approved as printed.

The report of Committee E-6 on Papers and Publications was presented by the chairman, C. L. Warwick. On motion, the report of the committee was adopted.

The report of Committee E-9 on Correlation of Research, H. F. Moore, chairman, was presented by G. K. Burgess. This report discussed briefly the work of the committee during the year and reviewed the various research projects being carried on by the Society's committees and through joint activities. On motion, the report of the committee was adopted.

The report of Committee E-5 on Standing Committees presenting a number of modifications in the Regulations Governing Standing Committees affecting the procedure of committee work, was presented by the chairman, C. L. Warwick. On motion, the report of the committee was adopted.

The report of the Committee of Tellers, consisting of L. S. Marsh and R. B. Rouse, appointed to canvass the letter ballot on election of officers, was received. The tellers reported that 1303 legal ballots had been cast, the votes being as follows:

For President, to serve for one year: G. W. Thompson, 1303 votes.
For Vice-President, to serve for two years: K. G. Mackenzie, 1299 votes.
For Members of Executive Committee, to serve for two years:

T. R. Lawson, 1298 votes.
H. S. Mattimore, 1293 votes.
P. D. Merica, 1288 votes.
S. T. Wagner, 1288 votes.

In accordance with the ballot the Chair declared the officers, listed above, elected.

The chairman then requested Past-Presidents A. A. Stevenson and G. K. Burgess to escort the President-elect to the chair. The President-elect, G. W. Thompson, expressed his appreciation of the honor of his election to the Presidency and pledged his best efforts to live up to the responsibilities imposed, expressing the hope that his administration might prove to be a worthy successor of the years that had passed and a precursor of better years to come.

The Vice-President-elect, K. G. Mackenzie, was escorted to the chair by Past-Presidents W. H. Fulweiler and J. H. Gibboney. He thanked the members for the honor bestowed upon him, deeming it an especial privilege to serve under the newly elected President, with whom he had been associated in activities both in this Society and elsewhere.

The meeting then adjourned and the Second and Third Sessions were immediately convened.

SECOND SESSION—TUESDAY, JUNE 26, 3 P. M.

On Wrought Iron and Cast Iron

(Held Simultaneously with the Third Session)

President H. F. Moore in the chair.

The report of Committee A-2 on Wrought Iron was presented by the chairman, H. W. Faus. The proposed revisions of the Standard Specifications for Staybolt, Engine-Bolt and Extra-Refined Wrought-Iron Bars (A 84 – 27) were accepted for publication as tentative as recommended by the committee. The proposed Tentative Specifications for Iron and Steel Chain submitted by the committee were accepted for publication as tentative. These had been prepared jointly by Committee A-2 and Committee A-1 on Steel and had been approved by the latter committee to supersede when adopted the present Standard Specifications for Iron and Steel Chain (A 56 – 24). On motion, the report of the committee was adopted.

The report of Committee A-3 on Cast Iron was presented by the chairman, R. S. MacPherran. The proposed Tentative Specifications for the Arbitration Test Bar and Tension Test Specimen for Cast Iron, with certain editorial corrections suggested from the floor of the meeting, were accepted for publication as tentative, superseding the present tentative revisions of the Standard Specifications for Gray-Iron Castings (A 48 – 18); for Cast-Iron Soil Pipe and Fittings (A 74 – 18); and for High-Test Gray-Iron Castings (A 88 – 24).

In presenting the Report on Correlation Tension and Transverse Tests of Cast Iron, appearing as an appendix to the report of the committee, additional test data were presented with the request that these be published subject to the approval of Committee E-6 on Papers and Publications.

Announcement was made that the newly elected officers of the committee were Hyman Bornstein, chairman; E. J. Lowry, vice-chairman; and F. B. Coyle, secretary. The committee expressed its appreciation of the services of the retiring chairman and a resolution of appreciation was presented and unanimously adopted. On motion, the report of the committee was adopted.

A paper entitled "A Study of Centrifugally-Cast Pipe (Metal-Mold Process) *versus* Sand-Cast Pipe," by F. N. Menefee and A. E. White, was presented by Mr. Menefee and discussed.

An oral report of progress on behalf of the Sectional Committee on Specifications for Cast-Iron Pipe was presented by the chairman, T. H. Wiggin. On motion, the report of the committee was received.

A paper entitled "The Static and Fatigue Properties of Some Cast Irons," by J. B. Kommers, was presented by the author and discussed.

A paper entitled "The Effect of Sulfur on the Physical Properties of Gray Iron," by Edwin K. Smith and Fred B. Riggan, was presented from manuscript by Mr. Riggan and discussed.

The meeting then adjourned till 8 P. M.

THIRD SESSION—TUESDAY, JUNE 26, 3 P. M.

On Rubber, Textiles, Coal and Timber

(Held Simultaneously with the Second Session)

Mr. W. F. Edwards, in the chair.

The report of Committee D-13 on Textile Materials, W. F. Edwards, chairman, was presented by the secretary, K. B. Cook. The proposed revisions of the Tentative Specifications for Tolerances and Test Methods for Knit Goods (D 231 - 25 T) recommended by the committee were accepted, the specifications being continued as tentative. The proposed Tentative Specifications for Tolerances and Test Methods for Asbestos Yarns; Specifications and Tolerances for 23/5/3 Carded American Tire Cord; and Definitions of Terms Relating to Textile Materials were accepted for publication as tentative. The committee had included in its report as preprinted a recommendation for the advancement to standard of the tentative definitions for the terms "regain (moisture regain)," "loop knot" and "gage." In view of certain criticisms that had been received from Committee E-8 on Nomenclature and Definitions the committee withdrew its recommendation for advancing these definitions to standard and recommended that they be continued as tentative in their present form. On motion, the report of the committee was adopted.

The report of Committee D-11 on Rubber Products was presented by the chairman, F. G. Breyer. One of the recommendations appearing in the report, namely the acceptance as tentative of specifications for fire hose prepared by the Sectional Committee on Specifications for Rubber-Lined Fire Hose to supersede the present Standard Specifications for Cotton Rubber-Lined Fire Hose for Private Fire Department Use (D 14 - 23) and Standard Specifications for Cotton Rubber-Lined Fire Hose for Public Fire Department Use (D 26 - 23), referred to the work of the sectional committee. Accordingly, the report of this committee was called for and it was presented by the chairman, P. L. Wormeley. On motion, the report of the sectional committee was received for publication.

On the recommendation for the acceptance as tentative of the proposed Tentative Specifications for Cotton Rubber-Lined Fire Hose for Public and Private Fire Department Use, prepared by the Sectional Committee on Specifications for Rubber-Lined Fire Hose, objection was raised to two notes appearing in these specifications, one to Section 2 (*b*) and one to Section 14. On motion, these notes reading as follows were eliminated from the specifications:

NOTE.—It is not the intention to exclude under these specifications any form of cotton cover which is not accurately described in the foregoing. Any form of cotton jacket which by virtue of strength and workmanship conforms to performance requirements specified in Sections 15 to 17 inclusive, shall be considered as included in these specifications.

NOTE.—This requirement is not intended to exclude certain types of construction in which the lining is wholly or partially uncemented to the cotton jackets. Any such constructions shall be considered with reference to the compliance of the hose with the general requirements of these specifications, and if found to have merit shall be recognized accordingly.

With these omissions the specifications were accepted for publication as tentative. On motion, Specifications D 14 – 23 and D 26 – 23 were withdrawn.

On the recommendation of the committee the withdrawal of the Standard Specifications for Rubber Belting for Power Transmission (D 53 – 24) was approved.

The proposed Methods of Chemical Analysis of Rubber Products submitted by the committee to supersede the requirements for the long procedure for chemical analysis appearing in the Standard Methods of Testing Rubber Products (D 15 – 24) was accepted for publication as tentative.

The committee proposed revisions of the Tentative Specifications for Insulated Wire and Cable: 30-per-cent Hevea Rubber (D 27 – 21 T). These revisions agree in substance, although not entirely in form, with the Specifications for 30-per-cent Rubber Insulation for Wire and Cable for General Purposes developed by a sectional committee under the rules of the American Engineering Standards Committee. The revisions were accepted, the specifications as revised being continued as tentative. The committee recommended the revision of the Tentative Specifications for Rubber Insulating Tape (D 119 – 27 T) by the inclusion of an illustration of the tape tester for making the fusion test of tape. In addition to this revision the committee recommended the elimination from Section 4 of the words "not more than 4 per cent of waxy hydrocarbons." The revisions, as recommended by the committee, were accepted, the specifications as revised being continued as tentative.

The committee recommended as a revision of the Standard Specifications for Adhesive Tape for General Use for Electrical Purposes (D 69 - 24) the inclusion of an illustration of the tape tester for testing the adhesion of tape. The committee recommended that this revision be adopted immediately and that the revisions proposed as tentative in 1927 be advanced to standard at the same time. The revisions were approved for reference to letter ballot for adoption as standard.

On motion, the report of the committee was adopted.

A paper entitled "An Explanation of Some of the Difficulties in Abrasion Testing of Rubber," by Harlan A. Depew, was presented by the author and discussed.

The report of Committee D-5 on Coal and Coke, in the absence of the chairman, A. C. Fieldner, was presented by the vice-chairman, H. C. Porter.

The proposed revision of the Standard Method of Laboratory Sampling and Analysis of Coal (D 271 - 27) was accepted for publication as tentative as recommended by the committee. The proposed Tentative Methods of Test for Cubic Foot Weight of Coke; of Test for Cubic Foot Weight of Crushed Bituminous Coal; of Test for Sieve Analysis of Coke; and of Tumbler Test for Coke, submitted by the committee, were accepted for publication as tentative.

In presenting the report mention was made of a request from the American Gas Association for the Society to appoint a representative on a committee to inaugurate a rather elaborate series of tests of the coals of the country for their gas-making and coke-making properties. This request had been referred to the Executive Committee. On motion, the report of the committee was adopted.

A paper entitled "Sampling of Pulverized Coal from Air Streams," by Lincoln T. Work, was presented from manuscript by the author.

The report of Committee D-7 on Timber was presented by the chairman, Hermann von Schrenk. The proposed revision of the Tentative Method of Test for Distillation of Creosote Oil (D 246 - 27 T) was accepted and the method of test was approved for reference to letter ballot of the Society for adoption as standard.

The report as preprinted had recommended the acceptance for publication as tentative of tables in preparation by the U. S. Bureau of Standards for specific gravity and volume correction of creosote oils. These tables had not become available and accordingly this recommendation was withdrawn. Provision had also been made to revise the Standard Methods of Sampling and Analysis of Creosote Oil (D 38 - 27) to refer to the proposed tables. This recommendation was similarly withdrawn.

On motion, the report of the committee was adopted.

The report of Committee C-5 on Fire Tests of Materials and Construction was presented by the acting chairman, R. P. Miller. On motion, the report of the committee was adopted.

The meeting then adjourned till 8 P. M.

FOURTH SESSION—TUESDAY, JUNE 26, 8 P. M.

On Testing, Wear Testing of Metals

President H. F. Moore in the chair.

The report of Committee E-1 on Methods of Testing, in the absence of the chairman, J. A. Capp, was presented by the secretary, R. E. Hess. On motion, the report of the committee was adopted.

A paper entitled "Methods of Particle Size Determination," by Lincoln T. Work, was presented from manuscript by the author. A round table discussion on the subject of particle size determination was held on the afternoon of the following day as a discussion of the paper.

A paper entitled "Concerning the Yield Point in Tension," by J. M. Lessells, was presented from manuscript by the author and discussed.

The following papers were presented by the authors and discussed:

"The Calibration of Rockwell Hardness Testing Machines," by F. S. Mapes;
"The Calibration of Extensometers," by R. L. Templin;
"Measurement of Brittleness," by P. L. Irwin.

The following papers comprising a Topical Discussion on Wear Testing of Metals were presented and discussed jointly:

"Wear and Mechanical Tests of Some Railroad Bearing Bronzes at Different Temperatures," by H. J. French—presented by the author;
"Wearing Tests of 12-per-cent Manganese Steel," by J. H. Hall—presented by the author;
"The Wearing Qualities of Tire Chains," by W. H. Parker—presented by the author;
"Wear Testing of Various Types of Steels," by J. M. Blake—presented by H. W. Gillett.

The meeting then adjourned till the following morning.

FIFTH SESSION—WEDNESDAY, JUNE 27, 9.30 A. M.

On Steel, Magnetic Testing

(Held Simultaneously with the Sixth Session)

Vice-President T. D. Lynch in the chair.

The report of Committee A-1 on Steel was presented by the chairman, J. B. Young. The proposed revisions of the Standard Specifications for Carbon-Steel and Alloy-Steel Forgings (A 18 – 27) and for Carbon-Steel Forgings for Locomotives (A 20 – 27) presented for the first time were unanimously approved for reference to letter ballot of the Society for adoption as standard, this recommendation requiring a nine-tenths vote. The proposed revisions of the following standards were accepted for publication as tentative as recommended by the committee:

Structural Steel for Bridges (A 7 – 24);
Structural Nickel Steel (A 8 – 24);
Structural Steel for Buildings (A 9 – 24);
Structural Silicon Steel (A 94 – 27);
Billet-Steel Concrete Reinforcement Bars (A 15 – 14);
Methods of Chemical Analysis of Plain Carbon Steel (A 33 – 24).

The report as preprinted contained a recommendation to revise the Tentative Specifications for Marine Boiler Steel Plates (A 114 – 27 T) in respect to the chemical composition and in respect to the requirements for marking. The committee withdrew the latter revision and recommended only the revision in respect to chemical composition. This revision, together with the proposed revisions of the Tentative Specifications for Structural Steel for Locomotives and Cars (A 113 – 27 T); for Electric Cast-Steel Anchor Chain (A 77 – 20 T); for Carbon-Steel Castings for Valves, Flanges and Fittings for High-Temperature Service (A 95 – 26 T); and for Lap-Welded and Seamless Steel Pipe for High-Temperature Service (A 106 – 27 T), were accepted, the specifications as revised being continued as tentative.

The Tentative Specifications for Forged or Rolled Steel Pipe Flanges for High-Temperature Service (A 105 – 27 T); and for Alloy Tool Steel (A 115 – 27 T) were approved for reference to letter ballot of the Society for adoption as standard.

The proposed Tentative Specifications for Black and Hot-dipped Zinc-Coated (Galvanized) Welded and Seamless Steel Pipe for Ordinary Uses; and for Iron and Steel Chain were accepted for publication as tentative, as recommended by the committee. The Specifications for Iron and Steel Chain had been prepared in conjunction with Committee A-2 on Wrought Iron to supersede, when adopted, the present Standard Specifications for Iron and Steel Chain (A 56 – 24). The specifications had received the approval of Committee A-2 and were being recommended by that committee as well for publication as tentative.

On motion, the report of the committee was adopted.

The report of the Joint Committee on Investigation of the Effect of Phosphorus and Sulfur in Steel was presented by the chairman, G. K. Burgess. On motion, the report was received for publication.

The report of the Research Committee on Yield Point of Structural Steel was presented by the chairman, M. O. Withey, and discussed. On motion, the report of the committee was received for publication.

A paper by C. H. Herty, Jr., and G. R. Fitterer entitled "Ferrous Silicates in Steel," had been scheduled for this session but the presentation of this paper was postponed until the Ninth Session, held on Thursday, June 28, at 9.30 A. M.

A paper entitled "Tests of Specimens Cut from Different Portions of Structural Steel Shapes," by M. O. Withey, was presented by the author and discussed.

The report of Committee A-4 on Heat Treatment of Iron and Steel in the absence of the chairman, H. M. Boylston, was presented by the secretary, J. H. Hall. The proposed new definitions to be added to the Tentative Definitions of Terms Relating to Heat Treatment Operations (A 119 - 27 T) were accepted for publication, the definitions being continued as tentative.

On motion, the report of the committee was adopted.

The report of Committee A-9 on Ferro-Alloys was presented by the chairman, N. B. Hoffman. On motion, the report of the committee was adopted.

The report of Committee A-6 on Magnetic Properties was presented by the chairman, Thomas Spooner. The Tentative Method of Test for Magnetic Properties of Iron and Steel at Low Inductions (A 34 - 27 T) revised as recommended by the committee, were approved for reference to letter ballot of the Society for adoption as standard to be added to the present Standard Methods of Test for Magnetic Properties of Iron and Steel (A 34 - 27).

On motion, the report of the committee was adopted.

The report of Committee A-8 on Magnetic Analysis was presented by the chairman, R. L. Sanford. On motion, the report of the committee was adopted.

The following papers were presented and discussed jointly:

"The Incremental Permeability Method for the Magnetic Analysis of High-Speed Steel," by W. B. Kouwenhoven and Julian D. Tebo—presented by Mr. Tebo;

"Endurance of High-Speed Cut-Off Tools in Relation to Magnetic and Other Measurements," by Haakon Styri—presented by the author.

The meeting then adjourned till 4 P. M.

SIXTH SESSION, WEDNESDAY, JUNE 27, 9.30 A. M.

On Petroleum Products, Electrical Insulating Materials and Preservative Coatings

(Held Simultaneously with the Fifth Session)

Past-President W. H. Fulweiler in the chair.

The report of Committee D-1 on Preservative Coatings for Structural Materials was presented by the chairman, Allen Rogers. The following proposed standards were accepted for publication as tentative:

Method of Test for Alkalinity or Acidity of Pigments;
Methods of Test for Bleeding of Pigments;
Methods of Test for Hygroscopic Moisture in Pigments;
Method of Test for Oil Absorption of Pigments;
Methods of Test for Mass Color and Tinting Strength of Pigments;
Routine Analysis of Dry Cuprous Oxide;
Routine Analysis of Dry Mercuric Oxide;
Specifications for the Toxic Ingredients in Anti-Fouling Paints.

The proposed revisions of the Standard Specifications for Raw Linseed Oil (D 234 – 27); and Methods of Routine Analysis of Dry Red Lead (D 49 – 27) presented for the first time were unanimously approved for reference to letter ballot of the Society for adoption as standard, this recommendation requiring a nine-tenths vote. The proposed revisions of the following standards were accepted for publication as tentative as recommended by the committee:

Methods of Routine Analysis of Titanium Pigments (D 186 – 27);
Method of Test for Coarse Particles in Paint Pigments (D 185 – 27);
Methods of Testing Shellac (D 29 – 25).

The proposed revisions of the definitions of terms published as tentative revisions of the Standard Definitions of Terms Relating to Paint Specifications (D 16 – 24) were accepted, the definitions being continued as tentative.

The proposed revisions of the Tentative Specifications for Boiled Linseed Oil (D 260 – 27 T); for Aluminum Powder for Paints (D 266 – 27 T); for Gold Bronze Powder (D 267 – 27 T); and Methods of Routine Analysis of White Linseed Oil Paints (D 215 – 27 T), were accepted, the specifications and methods being continued as tentative.

The report as preprinted had recommended the revision and advancement to standard of a number of specifications for pigments. The committee withdrew from this group the recommendation for revision and advancement to standard of the Tentative Specifications for Titanium Barium Pigments (D 265 – 27 T). The remaining specifications and methods in this group, as revised, were approved for reference to letter ballot of the Society for adoption as standard as follows:

Specifications for Prussian Blue (D 261 – 27 T);
Specifications for Ultramarine Blue (D 262 – 27 T);
Specifications for Chrome Oxide Green (D 263 – 27 T);
Specifications for Commercial Para Red (D 264 – 27 T);
Method of Test for Elasticity or Toughness of Varnishes by Means of Addition of Linseed Oil (D 154 – 26 T);
Method of Test for Determination of Wax in Shellac ("Machine-Made" and Dry-Bleached Refined Shellac) (D 29 – 27 T).

On motion, the report of the committee was adopted.

The report of Committee D-17 on Naval Stores was presented by the chairman, F. P. Veitch. On motion, the report of the committee was adopted.

The report of Committee D-15 on Thermometers, W. H. Fulweiler, chairman, was presented by the secretary, C. S. Reeve. The committee submitted three new specifications for thermometers. Of these the proposed specification for the thermometer for specific gravity of petroleum products was being submitted by Committee D-2 on Petroleum Products and Lubricants as a part of its proposed Tentative Method of Test for Gravity of Petroleum and Petroleum Products by Means of the Hydrometer. The proposed specification for the thermometer for heating test for raw tung oil had been referred to Committee D-1 for consideration as a substitute for the present specifications appearing in the Tentative Specifications for Raw Tung Oil. The remaining specification, covering thermometers for Engler viscosimeters, although referred to in the report as preprinted as a proposed specification, was submitted for publication as tentative. This recommendation of the committee was approved.

On motion, the report of the committee was adopted.

The report of Committee D-9 on Electrical Insulating Materials was presented by the chairman, H. S. Vassar. The proposed revision of the Standard Methods of Testing Molded Insulating Materials (D 48 – 27) was accepted for publication as tentative. The proposed revisions of the following tentative methods were accepted, the methods being continued as tentative:

Methods of Testing Insulating Varnishes (D 115 - 26 T);
Methods of Testing Electrical Porcelain (D 116 - 27 T);
Methods of Testing Untreated Insulating Paper (D 202 - 27 T);
Methods of Testing Laminated Sheet Insulating Materials (D 229 - 26 T);
Methods of Testing Insulating Materials for Resistance to Impact (D 256 - 26 T).

The proposed Tentative Methods of Testing Varnished Cloth Tapes were accepted for publication as tentative as recommended by the committee.

The withdrawal of the Tentative Methods of Testing Electrical Insulating Materials for Voltage Effects at Radio Frequencies (D 175 - 25 T), recommended by the committee, was approved.

On motion, the report of the committee was adopted.

The report of Committee D-2 on Petroleum Products and Lubricants was presented by the chairman, F. A. Hull. The proposed Tentative Method of Test for Distillation of Crude Petroleum; of Test for the Determination of Autogenous Ignition Temperatures; of Test for Gravity of Petroleum and Petroleum Products by Means of the Hydrometer; and Definitions of Terms Relating to Petroleum were accepted for publication as tentative. The proposed revision of the Tentative Method of Test for Melting Point of Petrolatum (D 127 - 24 T) was accepted for publication, the method being continued as tentative.

The Tentative Methods of Test for Saponification Number (D 94 - 21 T); of Test for Cloud and Pour Points of Petroleum Products (D 97 - 27 T); of Testing Gas Oils (Gravity, Distillation, Sulfur, Carbon Residue, Pour Point, Viscosity, Water) (D 158 - 25 T); and of Test for Carbon Residue of Petroleum Products (Conradson Carbon Residue) (D 189 - 27 T), were approved for reference to letter ballot of the Society for adoption as standard.

The proposed revisions of the Standard Methods of Test for Steam Emulsion of Lubricating Oils (D 157 - 27); of Test for Water in Petroleum Products and Other Bituminous Materials (D 95 - 27); and of Test for Water and Sediment in Petroleum Products by Means of Centrifuge (D 96 - 24) presented for the first time were unanimously approved for reference to letter ballot of the Society for adoption as standard, this recommendation requiring a nine-tenths vote.

In addition to the recommendations concerning standards and tentative standards appearing in the report as preprinted the committee recommended the following editorial revisions of the Tentative Method of Test for Penetration of Greases and Petrolatum (D 217 - 27 T):

Section 2.—Change the first sentence to read as follows by the addition of the italicized words and the omission of those in brackets:

> 2. *The consistency shall be determined by measuring* the penetration [shall be measured] on what is customarily known as an asphalt penetrometer such as that described in the *Proceedings* of the American Society for Testing Materials, Vol. VII, p. 626 (1907), and illustrated in Fig. 3 herein.

Section 13.—In the second and fifth lines, change the word "consistency" to "penetration."

The chairman then called on Mr. Lunn, chairman of the Sub-Committee on Application of Tests, to present the report on "Significance of Tests for Petroleum Products," appearing as an appendix to the report of Committee D-2.

On motion, the report of the committee was adopted.

A paper entitled "The How and Why of Gasoline Performance," by J. Bennett Hill, was presented by the author and discussed.

A paper entitled "The Significance of Various Tests Applied to Motor Oils," by Robert E. Wilson and D. P. Barnard, 4th, was presented by Mr. Wilson and discussed.

The meeting then adjourned till 4 P. M.

SEVENTH SESSION—WEDNESDAY, JUNE 27, 4 P. M.

Edgar Marburg Lecture and Award of Charles B. Dudley Medal

President H. F. Moore in the chair.

The President introduced Dr. Frank B. Jewett, President and Director of the Bell Telephone Laboratories and a Vice-President of the American Telephone and Telegraph Co., as the Third Edgar Marburg Lecturer. Doctor Jewett chose as his subject "Some Research Problems Involved in Transoceanic Telephony." In this he followed the development of transoceanic telephony from the first trials made in 1915 to the opening of commercial service in June, 1927. The technical difficulties had been many but probably one of the greatest contributions that had made the service practicable was the development of high-power vacuum tubes, 10 kw. tubes being now in use. He also mentioned the administrative difficulties such as the harmonizing of different operating methods in America and Europe and the clearing by international action of the frequency channel. The lecture was concluded with a motion picture illustrating the method of putting through a call from America to England. President Moore in thanking Doctor Jewett for his lecture, presented to him on behalf of the Society the Edgar Marburg Lecture Certificate.

Following the lecture the second award of the Charles B. Dudley Medal was made to Mr. A. V. de Forest for his paper on "A Method of Graphic Representation of Magnetic Characteristics." Mr. de Forest was presented to the President by Mr. R. L. Sanford, a leader in the field of magnetic testing, as follows:

> Mr. President, members of the Society and guests: The value to a society of any individual should be measured not only in terms of tangible evidences of successful achievement, but also in terms of the less tangible though no less real things of the spirit. The paper chosen as meriting the award of the Charles B. Dudley Medal is tangible evidence of successful achievement of no mean order. The paper is entitled "A Method of Graphic Representation of Magnetic Characteristics." The method therein described makes real to a degree hitherto unattained, the magnetic characteristics of materials, and demonstrates as does no other method, the effect of various influences upon them. Its use should materially aid in the solution of many puzzling problems encountered in the development of magnetic analysis.
>
> The less tangible contributions of its author can be attested by the members of the committee through whose auspices that paper was presented; for in all of the activities of the committee and particularly in its personal association, the unbounded enthusiasm, dogged perseverance and unfailing optimism of its secretary have been the source of inspiration and help. It was with great satisfaction therefore that the members of the committee learned that the tangible evidence of successful achievement wrought through the exercise of these qualities, coupled with experimental ingenuity amounting to genius had been deemed worthy of the honor about to be conferred.
>
> It gives me pleasure therefore to present A. V. deForest, research engineer of the American Chain Co., to receive the Dudley Medal.

The award was made by the President. Mr. de Forest in receiving the medal referred to the work of the Society's Committee on Magnetic Analysis that had led to his investigations described in the paper:

> Gentlemen, it is with a great deal of pleasure and a good deal of emotion that I receive such recognition extended by such a society to such a new and relatively unknown science as magnetic analysis. Our old friends, the ferrous metals, the most complicated system of alloys in the world and the least known of our physical phenomena, are here associated together to bring about a betterment for engineering use and assist the rather crude and rather haphazard development of our commercial steels. The entire membership of Committee A-8 should, in actual justice, receive this medal, for it is only through the hearty cooperation and inspiration of all the members of that committee that this work has been made possible.

The meeting then adjourned till 8 P. M.

EIGHTH SESSION—WEDNESDAY, JUNE 27, 8.15 P. M.

Presidential Address and Report of Executive Committee

Past-President J. H. Gibboney in the chair.

The secretary presented the annual report of the Executive Committee, which discussed membership activities, the work of the standing committees, publications, finances and administrative matters relating to committee activities and relations with other societies.

The Executive Committee recommended the revision of the By-laws as follows:

Amend Article VI, Section 1, of the By-laws by inserting the following paragraph between the third and fourth paragraphs of the present section:

> Approval of modifications proposed on the floor of the annual meeting, of recommendations approved by the required letter ballot vote of the appropriate standing committee affecting standards and tentative standards, shall be contingent upon subsequent approval of such proposed modifications by letter ballot vote of the standing committee concerned; provided that if such proposed modifications fail of such subsequent approval, the original recommendations of the committee shall prevail and the proposed modifications be referred to the committee for study and report at the next annual meeting.

On motion, the revision of the By-laws was accepted and referred to letter ballot of the Society for adoption.

On motion, the report of the Executive Committee was adopted.

The chairman introduced President H. F. Moore, who presented his Presidential Address. The address dealt with the 250th anniversary of Robert Hooke's public announcement of the law of proportionality of stress to strain. President Moore portrayed Hooke as being among the first to use actual experiment in developing laws of natural phenomena, those before this time preferring to develop their laws through logic alone. His methods, perforce, were crude and in stating his conclusions, few if any data were given. The science of experimentation and of testing remained to be developed, leading up to the highly developed science of the present day.

The meeting then adjourned till the following morning.

NINTH SESSION—THURSDAY, JUNE 28, 9.30 A. M.

Metals: Corrosion, Fatigue and Properties at Elevated Temperatures

President H. F. Moore in the chair.

The report of Committee A-5 on Corrosion of Iron and Steel was presented by the chairman, J. H. Gibboney. In so doing the chairman called on F. N. Speller to present the report of the Sub-Committee on Total Immersion Tests and on H. E. Smith to present the report of the Committee on Inspection of Field Tests of Metallic Coatings.

The proposed Specifications for Zinc-Coated (Galvanized) Steel Wire Strand; and for Zinc-Coated (Galvanized) Barb Wire were accepted for publication as tentative as recommended by the committee.

On motion, the report of the committee was adopted.

The report of the Sectional Committee on Zinc Coating of Iron and Steel, in the absence of the chairman, J. A. Capp, was presented by the vice-chairman, C. S. Trewin. The proposed Specifications for the Zinc Coating on Iron and Steel Sheets were accepted for publication. The proposed Specifications for Zinc (Hot-Galvanized) Coatings on Structural Steel Shapes, Plates and Bars and Their Products were accepted for publication as a tentative A.S.T.M. standard.

On motion, the report of the sectional committee was received for publication.

A paper entitled "Gas Welding of High-Chromium Corrosion-Resistant Alloys," by W. B. Miller, was presented by J. R. Dawson and discussed.

The following papers were presented and discussed jointly:

"Some Factors Involved in Corrosion and Corrosion-Fatigue of Metals," by D. J. McAdam, Jr.—presented by the author;

"Influence of Corrosion Accelerators and Inhibitors on Fatigue of Ferrous Metals," by F. N. Speller, I. B. McCorkle and F. P. Mumma—presented by Mr. Speller.

The following papers were presented and discussed:

"Long-Time" or "Flow" Tests of Carbon Steels at Various Temperatures with Particular Reference to Stresses Below the Proportional Limit," by J. J. Kanter and L. W. Spring—presented by Mr. Kanter;

"Testing of Materials at Elevated Temperatures," by P. G. McVetty—presented by the author;

"The Seizing of Metals at High Temperatures," by N. L. Mochel—presented by the author.

The report of the Joint Research Committee of the A.S.M.E. and the A.S.T.M. on Effect of Temperature on the Properties of Metals in the absence of the chairman, G. W. Saathoff, was presented by the secretary, F. M. Van Deventer. The report of the committee was accepted and the recommendation of the committee that certain data that might become available be published was approved.

The paper entitled "Ferrous Silicates in Steel," by C. H. Herty, Jr., and G. R. Fitterer, postponed from the previous day, was presented by Mr. Herty.

The meeting then adjourned till 8 P. M.

TENTH SESSION—THURSDAY, JUNE 28, 8 P. M.

On Non-Ferrous Metals and Metallography

(Held Simultaneously with the Eleventh Session)

Mr. W. B. Price in the chair.

The report of Committee B-1 on Copper Wire in the absence of the chairman, J. A. Capp, was presented by W. H. Bassett. The recommendation that the Standard Specifications for Hard-Drawn Copper Wire (B 1 - 27) be referred to the American Engineering Standards Committee for approval as American Standard was approved.

On motion, the report of the committee was adopted.

The report of Committee B-2 on Non-Ferrous Metals and Alloys was presented by the chairman, William Campbell. In presenting the report the chairman called on H. A. Anderson to present the report of Sub-Committee XV on Die Casting Alloys and on N. L. Mochel to present some substantiating data in respect to melting points of silver solders referred to in the proposed Tentative Specifications for Silver Solders.

The proposed Specifications for Fire-Refined Copper Other than Lake; for Seamless Copper Tubes; for Sand Castings of the Alloy: Copper 80 per cent; Tin 10 per cent; Lead 10 per cent; and for Silver Solders were accepted for publication as tentative as recommended by the committee.

The proposed revisions of the following standards were accepted for publication as tentative:

Specifications for Free-Cutting Brass Rod for Use in Screw Machines (B 16 - 18);
Specifications for Naval Brass Rods for Structural Purposes (B 21 - 27);
Specifications for Bronze Bearing Metal in Ingot Form (B 31 - 21);
Methods of Chemical Analysis of Manganese Bronze (B 27 - 19).

The following tentative specifications were approved for reference to letter ballot of the Society for adoption as standard:

- Specifications for Brazing Solder (B 64 – 27 T);
- Specifications for Aluminum Bronze Castings (B 59 – 26 T);
- Specifications for Sand Castings of the Alloy: Copper 88 per cent; Tin 8 per cent; Zinc 4 per cent (B 60 – 26 T);
- Specifications for Steam or Valve Bronze Sand Castings (B 61 – 26 T);
- Specifications for Composition Brass or Ounce Metal Sand Castings (B 62 – 26 T);
- Specifications for Yellow Brass Sand Castings for General Purposes (B 65 – 27 T);
- Specifications for Bronze Castings in the Rough for Locomotive Wearing Parts (B 66 – 27 T);
- Specifications for Car and Tender Journal Bearings, Lined (B 67 – 27 T).

The proposed Specifications for Brass Ingot Metal, Graded and Ungraded, for Sand Castings were accepted for publication to supersede the present standard specifications.

On the recommendation of the committee the withdrawal of the Standard Specifications for Brass Ingot Metal, Graded and Ungraded, for Sand Castings (B 30 – 22) was approved.

The proposed revisions of the Tentative Methods of Chemical Analysis of Aluminum and Light Aluminum Alloys (B 40 – 27 T) were accepted, the methods being continued as tentative.

On motion, the report of the committee was adopted.

A paper entitled "Some Mechanical Properties of Nickel, Manganese-Nickel and Copper-Nickel Alloys," by William A. Mudge and Leroy W. Luff, was presented by Mr. Mudge and discussed.

The report of Committee B-4 on Metallic Materials for Electrical Heating was presented by the chairman, Dean Harvey. The proposed Tentative Methods of Determination of Sulfur in Metallic Materials for Electrical Heating were accepted for publication to be added to the Tentative Methods of Chemical Analysis of Metallic Materials for Electrical Heating (B 71 – 27 T), the methods being continued as tentative.

On motion, the report of the committee was adopted.

The report of Committee B-3 on Corrosion of Non-Ferrous Metals and Alloys was presented by the chairman, T. S. Fuller.

On motion, the report of the committee was adopted.

The report of Committee E-4 on Metallography was presented by the chairman, H. C. Boynton. It had been expected that further reports would be available on behalf of Sub-Committee II on Nomenclature and Definitions and Sub-Committee VI on X-ray (Crystal Analysis). These reports, however, were not as yet available and would be included in the next year's report.

On motion, the report of the committee was adopted.

The meeting then adjourned till the following morning.

ELEVENTH SESSION—THURSDAY, JUNE 28, 8 P. M.

On Nomenclature, Waterproofing, Road Materials and Aggregates

(Held Simultaneously with the Tenth Session)

Vice-President G. W. Thompson in the chair.

The report of Committee E-8 on Nomenclature and Definitions was presented by the chairman, Cloyd M. Chapman. The report as preprinted recommended the revision and advancement to standard of the Tentative Definition of the Term Screen (Sieve) (E 13 – 26 T) and of the Tentative Definitions of the Terms Sand and Aggregate (C 58 – 26 T). Objection was raised on behalf of Committee D-4 on Road and Paving Materials to the advancement to standard of the Definitions of the Terms Screen and Aggregate on the ground that this committee had standard definitions for these terms and wished to have an opportunity to withdraw these definitions before the new definitions were adopted as standard. The definitions for these terms, as revised, were accordingly continued as tentative. The Definition of the Term Sand was approved for reference to letter ballot of the Society for adoption as standard.

The report contained as information a definition for the term concrete. Committee D-4 had adopted in 1925 a note which it recommended be included with the definition for concrete as a substitute for the note suggested by Committee E-8. It now recommended that this note be included as information with the definition proposed by Committee E-8, the note reading as follows:

> NOTE.—The term concrete without descriptive adjective is indefinite and unspecific and should be always used with a qualifying adjective, indicating the cementing material which is present, *i.e.*, "asphaltic concrete," "coal tar concrete," "portland cement concrete," etc.

The motion to amend the report of Committee E-8 in this respect was adopted after a division had been called for, resulting in a vote of 18 affirmative and 14 negative.

On motion, the report of the committee as amended was adopted.

The report of Committee D-8 on Bituminous Waterproofing and Roofing Materials was presented by the chairman, S. T. Wagner. The Tentative Method of Test for Steam Distillation of Bituminous Protective Coatings (D 255 - 26 T) was approved for reference to letter ballot of the Society for adoption as standard. The report as preprinted recommended changes in the titles in the Specifications for Slate-Surfaced Asphalt Roll-Roofing and Slate-Surfaced Asphalt Shingles (D 225 - 27); for Heavy Weight Slate-Surfaced Asphalt Roll-Roofing and Heavy Weight Slate-Surfaced Asphalt Shingles (D 249 - 27); and Methods of Testing Asphalt Roll-Roofing Surfaced with Fine or Granular Talc, Slate Surfaced Asphalt Roll-Roofing and Slate-Surfaced Asphalt Shingles (D 228 - 27), the changes to be published as tentative revisions of the specifications. Modifications of the suggested titles were made by the committee and on the recommendation of the committee these modified wordings were accepted as editorial revisions of the standard specifications to become effective immediately, the modified titles reading as follows:

Standard Specifications for Asphalt Roll-Roofing and Asphalt Shingles Surfaced with Mineral Granules (D 225 - 27);

Standard Specifications for Heavy Weight Asphalt Roll-Roofing and Heavy Weight Asphalt Shingles Surfaced with Mineral Granules (D 228 - 27);

Standard Methods of Testing Asphalt Roll-Roofing Surfaced with Fine Talc, Granular Talc, or Mineral Granules, Likewise Asphalt Shingles Surfaced with Mineral Granules (D 228 - 27).

Corresponding editorial changes would be required in the texts of the specifications changing the words "slate surfaced" to "surfaced with mineral granules" wherever these words appear.

A paper entitled "The Volatile Combustible Test as Applied to Coal-Tar Pitch," by S. R. Church and W. H. Fulweiler, was presented from manuscript by Mr. Church.

The report of Committee D-4 on Road and Paving Materials in the absence of the chairman, Julius Adler, was presented by R. W. Crum. The proposed revisions of the following tentative standards were accepted, the specifications and methods of test being continued as tentative:

Specifications for High-Carbon Tar Cement for Use Cold in Repair Work (Cut-Back Product) (D 106 - 27 T);
Specifications for Low-Carbon Tar Cement for Use Cold in Repair Work (Cut-Back Product) (D 107 - 27 T);
Method of Test for Residue of Specified Penetration (D 243 - 26 T);

Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment (D 20 - 27 T);
Methods of Testing Bituminous Emulsions (D 244 - 26 T).

The Tentative Method of Decantation Test for Sand and Other Fine Aggregates (D 136 - 22 T) was approved for reference to letter ballot of the Society for adoption as standard.

The proposed Method of Test for Abrasion of Gravel and Recommended Practice for Bituminous Paving Plant Inspection were accepted for publication as tentative as recommended by the committee.

On motion, the report of the committee, with certain editorial changes in the proposed Specifications for Portland-Cement Concrete for Pavements and for Pavement Base appearing as an appendix to the report, was adopted.

A paper entitled "Studies of Methods of Making Deval Abrasion Tests of Aggregates," by Stanton Walker, was presented by the author and discussed.

The meeting then adjourned till the following morning.

TWELFTH SESSION—FRIDAY, JUNE 29, 9.30 A. M.

On Brick, Tile, Refractories, Slate and Stone

(Held Simultaneously with the Thirteenth Session)

Mr. H. T. Shelley in the chair.

The report of Committee C-3 on Brick was presented by the chairman, T. R. Lawson. The proposed Specifications for Concrete Building Brick to replace the Tentative Specifications for Concrete Building Brick (C 55 - 24 T); and for Sand-Lime Building Brick were accepted for publication as tentative as recommended by the committee. The proposed revisions of the Tentative Specifications for Building Brick (Made from Clay or Shale) (C 62 - 27 T), for Paving Brick (C 7 - 27 T), and Methods for Testing Brick (C 67 - 27 T) were accepted for publication, the specifications and methods being continued as tentative.

On motion, the report of the committee was adopted.

A paper entitled "The Effect of Strength of Brick on Compressive Strength of Brick Masonry," by J. W. McBurney, was presented by the author and discussed.

The report of Committee C-10 on Hollow Masonry Building Units, in the absence of the chairman, D. E. Parsons, was presented by the secretary, H. D. Foster. The proposed revisions of the Standard Specifications and Tests for Hollow Burned-Clay Load-Bearing Wall Tile (C 34 - 27) and for Hollow Burned-Clay Floor Tile (C 57 - 27) were accepted for publication as tentative. The proposed revision of the Tentative Specifications and Tests for Hollow Burned-Clay Fireproofing, Partition and Furring Tile (C 56 - 27 T), were accepted, the specifications being continued as tentative.

On motion, the report of the committee was adopted.

The report of Committee C-8 on Refractories, in the absence of the chairman, G. A. Bole, was presented by the secretary, L. J. Trostel. The following tentative standards were approved for reference to letter ballot of the Society for adoption as standard:

Specifications for Clay Fire Brick for Malleable Furnaces with Removable Bungs and for Annealing Ovens (C 63 - 27 T);
Specifications for Clay Fire Brick for Stationary Boiler Service (C 64 - 27 T);
Specifications for Clay Fire Brick for Marine Boiler Service (C 65 - 27 T);
Definitions of Terms Relating to Refractories (fire clay, plastic or bond fire clay, flint fire clay, diaspore clay and nodular fire clay) (C 71 - 27 T), revised as recommended by the committee.

The definitions of the remaining terms, namely, for spalling and pyrometric cone equivalent, were continued as tentative.

The tentative revisions of the Standard Method of Test for Softening Point of Fire-Clay Brick (C 24 - 20) and Definitions for Clay Refractories (C 27 - 20), were approved for reference to letter ballot of the Society for adoption as standard.

On motion, the report of the committee was adopted.

A paper entitled "Methods of Measuring the Thermal Conductivity of Insulating and Refractory Materials," by M. L. Hartmann, O. B. Westmont and C. E. Weinland, was presented from manuscript by William Van Arnam.

A paper entitled "The Development of an Apparatus for Wear Tests on Flooring Materials," by D. W. Kessler, was presented from manuscript by the author and discussed.

A paper entitled "Staining and Efflorescence on Indiana Limestone Caused by Moisture Seepage Through Backing Masonry Materials," by Lee Huber, was presented by the author and discussed.

The report of Committee D-16 on Slate was presented by the chairman, D. W. Kessler.

On motion, the report of the committee was adopted.

The report of Committee D-18 on Natural Building Stones in the absence of the chairman, F. Y. Joannes, was presented by the secretary, H. S. Brightly. On motion, the report of the committee was adopted.

The meeting then adjourned till 8 P. M.

THIRTEENTH SESSION—FRIDAY, JUNE 29, 9.20 A. M.

On Cement, Lime, Gypsum and Drainage Pipe

(Held Simultaneously with the Twelfth Session)

Mr. Cloyd M. Chapman in the chair.

The report of Committee C-7 on Lime was presented by the chairman, H. C. Berry. The proposed revisions of the Standard Specifications for Hydrated Lime for Structural Purposes (C 6 – 24) were accepted for publication as tentative. The Tentative Definitions of Terms Relating to Lime (C 51 – 24 T), revised as recommended by the committee, were approved for reference to letter ballot of the Society for adoption as standard.

On motion, the report of the committee was adopted.

The report of Committee C-11 on Gypsum in the absence of the chairman, J. W. Ginder, was presented by the secretary, H. J. Schweim. The report as preprinted recommended the advancement to standard of five definitions of terms, comprising the Tentative Definitions of Terms Relating to the Gypsum Industry (C 11 – 27 T), subject to the approval of Committee E-8 on Nomenclature and Definitions. Of these the definitions of three terms had been approved by Committee E-8 as follows: gypsum molding plaster, gypsum pottery plaster, and Keene's cement and these were approved for reference to letter ballot of the Society for adoption as standard. The definitions for the remaining two terms, namely, gypsum plaster board and gypsum wall board, were continued as tentative. The proposed revised Specifications for Keene's Cement were accepted for publication, to supersede the present tentative specifications. The proposed Specifications for Calcined Gypsum for Use in the Preparation of Dental Plasters were accepted for publication as tentative.

On motion, the report of the committee was adopted.

The report of Committee C-1 on Cement was presented by the chairman, P. H. Bates. Discussion on this report was deferred until after the presentation of the next item on the program, a paper by E. M. Brickett. On motion, the report of the committee was adopted.

A paper entitled "A Plastic Mortar Compression Test for Cement," by Edward M. Brickett, was presented by the author and discussed jointly with the report of Committee C-1.

A paper entitled "Volume Changes of Portland Cement as Affected by Chemical Composition and Aging," by Alfred H. White, was presented by the author and discussed.

A paper entitled "Resistance of Portland-Cement Concrete to the Action of Sulfate Waters as Influenced by the Cement," by Dalton G. Miller, was presented by the author and discussed.

The report of Committee C-6 on Drain Tile in the absence of the chairman, Anson Marston, was presented by the secretary, W. J. Schlick. On motion, the report of the committee was adopted.

A paper entitled "Tests of Clay and Concrete Load-Bearing Pipe," by W. J. Schlick, was presented by the author.

A paper entitled "The A.S.T.M. Specifications for Sewer Pipe and the Fiber Strength of the Material," by F. B. Lysle, was presented by the author and discussed.

The report of the Joint Committee on Concrete Culvert Pipe in the absence of the chairman, Anson Marston, was presented by W. J. Schlick. On motion, the report of the committee was accepted for publication.

The meeting then adjourned till 8 P. M.

FOURTEENTH SESSION—FRIDAY, JUNE 29, 8 P. M.

On Concrete

President H. F. Moore in the chair.

The report of Committee C-9 on Concrete and Concrete Aggregates was presented by the chairman, Cloyd M. Chapman. The proposed revisions of the following tentative standards were accepted for publication, the specifications and methods being continued as tentative:

Specifications for Concrete Aggregates (C 33 – 26 T);
Methods of Test for Field Determination of Approximate Apparent Specific Gravity of Fine Aggregate (C 68 – 27 T);
Methods of Test for Field Determination of Approximate Percentage of Voids in Fine Aggregate (C 69 – 27 T);
Methods of Test for Field Determination of Surface Moisture in Fine Aggregate (C 70 – 27 T).

On motion, the report of the committee was adopted.

The following papers were presented and discussed jointly:

"The Determination of the Workability of Concrete," by Wallace F. Purrington and Harold C. Loring—presented by Mr. Purrington.

"The Measurement of Workability of Concrete," by George A. Smith—presented by George Conahey.

A paper entitled "Permeability of Concrete," by Ira L. Collier, was presented by the author and discussed.

A paper entitled "Some Accelerated Freezing and Thawing Tests on Concrete," by C. H. Scholer, was presented by the author and discussed.

The following papers were presented and discussed jointly:

"Compression, Flexure and Tension Tests of Plain Concrete," by H. F. Gonnerman and E. C. Shuman—presented by Mr. Gonnerman.

"The Effect of Several Mechanical Features of Testing on the Determination of the Flexural Strength of Plain Concrete," by T. F. Willis and F. N. Wray—in the absence of the authors presented by title.

A paper entitled "Experimental Tests of Concrete-Steel Bond," by L. N. Edwards and H. L. Greenleaf, was presented by Mr. Edwards and discussed.

The winners of the Golf and Tennis Tournaments were then announced and the prizes awarded by E. D. Boyer on behalf of the Entertainment Committee. The A.S.T.M. championship golf cup for the low score was won by H. G. Farmer, of Pittsburgh, Pa. The A.S.T.M. championship tennis cup was won by F. S. Crane, of Chicago, Ill.

Other prize winners in golf and tennis were: A. R. Small, F. G. Breyer, F. M. Hartley, G. H. Clamer, H. H. Morgan, J. J. Howard, E. S. Taylerson, W. H. McCune and R. J. McKay.

There being no further business, the Chair declared the Thirty-first Annual Meeting adjourned *sine die.*

HOOKE'S LAW OF STRESS AND STRAIN

AN ADDRESS COMMEMORATIVE OF THE TWO-HUNDRED-AND-FIFTIETH ANNIVERSARY OF ITS ANNOUNCEMENT

ANNUAL ADDRESS BY THE PRESIDENT

H. F. MOORE

JUNE 27, 1928

In 1678, a quarter-millennium ago this year, Robert Hooke, Professor of Geometry at Gresham College, London, delivered a public lecture under the title of "*De Potentia Restitutiva*" with the sub-title "Of Spring, Explaining the Power of Springing Bodies." In that lecture he announced the law of "springy" (or as we now say elastic) bodies, and being a seventeenth century college professor he announced it in Latin, "*Ut tensio sic vis*," which translated literally means "As the stretch, so the force," or translated in modern terms, "Strain is proportional to stress."

Ever since that time this statement has borne the name of Hooke's law. It is one of the basic assumptions of present-day computation of strength of materials; the routine computer, the testing engineer, and the mathematical elastician all accept it as a basis for their work. It has had an influence on the development of the mechanical age comparable to the first and the second laws of thermodynamics, comparable to Ohm's law of electric currents, comparable to the law of definite proportions in chemistry. No structural engineer designs a beam, no machine designer determines the size of a shaft, no testing engineer makes a transverse test or a torsion test without using reasoning or formulas based on this law. The great Galilei himself, perhaps the first materials engineer of history, lacking knowledge of this relation between force and elastic deformation, failed to establish methods for determining the strength of beams of any cross-section other than rectangular.

Charles II of England, the "merry monarch," left behind him a reputation of never saying a foolish thing, nor ever doing a wise one; but we must take exception to the latter part of the statement, for it was he who about 1660 signed the charter which authorized the existence of the Royal Society of London, which was described in Sir Christopher Wren's memorandum of organization as a "College for the Promoting of Physico-Mathematical Experimentall Learning." For a number of years enthusiastic students of science had met privately for discussion, but this good deed of the merry monarch brought the society into public view, and its meetings, the papers presented before it, and its atmosphere of free discussion and frank criticism have been perhaps the largest—certainly one of the largest—factors in the scientific progress of the English-speaking peoples.

Robert Hooke, born in 1635 on the Isle of Wight, the son of a clergyman, was a member of that group of scientific giants who established the young Royal Society of Great Britain in the place of eminence it has occupied ever since. Wren, Boyle, and the great Newton were contemporaries, as were the continental scientists Huyghens, Leibnitz, and James Bernoulli.

About the time that Charles II officially founded the Royal Society, young Hooke was acting as a sort of mechanician-assistant for Boyle in building and experimenting with his "pneumatic engine"—one of the earliest air pumps—and was devising clocks with spring-balance pendulums, in the course of which work he was led to the discovery of his law. In 1662, very shortly after the Royal Society was formally founded, we find Hooke elected to membership on the strength of a paper on capillary tubes and made "Curator of Experiments" for the society. He had been a member for nearly ten years when Newton was admitted. He was always at his best when making apparatus and performing experiments; he has been characterized as "the first mechanician of his day."

The biographer of the professors of geometry in Gresham College, John Ward, says of Hooke:

> "As to his person, he made but a mean appearance, being short of stature, very crooked, pale, lean and of a meager aspect, with lank brown hair . . . his features were not the most regular. . . . His inventive faculty was surprisingly great, which he imployed with indefatigable industry, always contenting himself with a little sleep and that very irregular. . . . This continual expense of spirits, accompanied with a recluse life, may be supposed to have easily produced a melancholy, accompanied with a mistrust and jealousy, which increased with his years. For at first he was very communicative of his discoveries and inventions, till, as he was wont to say, some persons improving upon his hints, published them for their own, which at last rendered him close and reserved even to a fault; by which means many things are lost, which he affirmed he knew."

Perhaps the above quotation explains why there seems to be no portrait of Hooke in existence—at least so the present Secretary of the Royal Society informs me. In this connection I cannot refrain from quoting another acquaintance of Hooke's, none other than Samuel Pepys, who in his famous diary under date of February 16, 1665, tells how at the Crown Tavern he met a company "of the most eminent worth," and says:

> "Above all Mr. Boyle was at the meeting, and above him Mr. Hooke who is the most, and promises the least, of any man in the world that I ever saw. Here excellent discourse till ten at night and then home."

Hooke was a lover of machines and apparatus rather than a formulator of laws, and while we can see his influence in modern time pieces, modern microscopes and modern shaft couplings, this one law is the only one he formulated. And doubtless he formulated this because it was one derived solely from experiment. Now in the early days of science, experiment was not looked on as a respectable means of study. Logic, reasoned laws founded on assumptions based on moral standards rather than on observation, were the tools of the respected scholar of science. This is illustrated vividly in the life of the sage of Syracuse, Archimedes, who, although he made many marvelous inventions, refused to write any of them up, regarding the work of an engineer mean and ignoble and altogether below that of the pure reasoner in mathematics.

It was Galilei who, against bitter opposition, made experimentation respectable in learned circles, but he combined logic and observation. Hooke was a pioneer in announcing his law on a purely experimental basis.

Apparently he undertook his study of elastic bodies in connection with a very commercial attempt to develop an invention. He became interested in devising means of determining the longitude of a ship at sea, by means of the apparent time shown by a clock, and recognizing that a clock with a swinging pendulum would not function properly on a rolling, pitching ship, he turned his attention to the development of a clock with a spring-balance pendulum. Commercially he was unsuccessful. There arose a bitter controversy between Hooke, Huyghens, and the Abbot de Hautefeuille of Orleans concerning priority of invention, and there developed a deadlock between Hooke and his financial backers over the details of contract as to continuance of royalty payments if others should "improve" Hooke's watch. Hooke emerged from this controversy embittered and secretive. In connection with his studies he had formulated his law, but he did not propose to give this to the public. For some fifteen or more years he kept this law secret, giving out occasional hints of its importance, and finally in 1675 he published an anagram "*ceiiinosssttuv*"—a mixed up pi of the letters composing the phrase "*ut tensio sic vis*"—as an appendix to a paper on "helioscopes." This practice, common enough in Hooke's day, seems a most curious proceeding to us to-day.

Imagine Jeffries and Archer announcing the slip-interference theory in the form of a cross-word puzzle! Apparently Hooke was urged to give his law to the world, for in 1678 he announced the law plainly in the lecture to which reference has already been made.

Now how precise, how inclusive, and how convincing were the experiments on which Hooke based his law? Perhaps no better answer can be given than a quotation of characteristic passages from his lecture:

> "The theory of Springs, though attempted by divers eminent Mathematicians of this Age, has hitherto not been Published by any. It is now about eighteen years since I first found it out, but designing to apply it to some particular use, I omitted the publishing thereof.
>
> "About three years since, His Majesty was pleased to see the Experiment that made out this Theory tried at White-Hall, as also my Spring Watch."

. . .

> "Now as the Theory is very short, so the way of trying it is very easie.
>
> "Take then a quantity of even-drawn Wire, either Steel, Iron, or Brass, and coyl it on an even Cylinder into a Helix of what number of turns you please, then turn the ends of the Wire into Loops, by one of which suspend this coyl upon a nail, and by the other sustain the weight that you would have to extend it, and hanging on several weights observe exactly to what length each of the weights do extend it beyond the length that its own weight doth extend it to, and you shall find that if one ounce, or one pound, or one certain weight doth lengthen it one line, or one inch, or one certain length, then two ounces, or two pounds, or two weights will extend it two lines, two inches, or two lengths; and three ounces, pounds or weights, three lines, inches, or lengths; and so forwards."

. . .

> "Or take a Wire string of twenty, or thirty, or forty foot long, and fasten the upper part thereof to a nail, and to the other end fasten a Scale to receive the weights; Then with a pair of Compasses take the distance of the bottom of the scale from the ground or floor underneath, and set down the said distance, then put in weights into the said scale in the same manner as in the former trials, and measure the several stretchings of the said string and set them down. Then compare the several stretchings of the said string, and you will find the same proportions one to the other that the weights do that made them.
>
> "The same will be found, if trial be made, with a piece of dry wood that will bend and return, if one end thereof be fixt in a horizontal posture, and to the other be hanged weights to make it bend downwards.
>
> "From all which it is very evident that the Rule or Law of Nature in every springing body is, that the force or power thereof to restore itself to its natural position is always proportionate to the Distance or space it is removed therefrom, whether it be by rarefaction, or a separation of its parts the one from the other, or by a Condensation, or crowding of those parts nearer together. Nor is it observable in these bodies only [which have been specifically discussed] but in all other springy bodies whatsoever, whether Metal, Wood, Stones, baked

Earths, Hair, Horns, Silk, Bones, Sinews, Glass, and the like. Respect being had to the particular figures of the bodies bended, and the advantagious or disadvantagious ways of bending them."

The above quotation is but a small part of Hooke's lecture on springs, but it is believed to be fairly representative of that lecture. There were given a few figures showing diagrams of springs loaded with weights, and a rather long discussion of solid matter as resisting penetration by the extremely rapid bumping together of the very small particles which constitute its ultimate elements. You may search the whole lecture through, and you will find no tables of test data, no graphs of results, no statement of the number of tests made, of the degree of precision of measurement, of the number of materials actually tested. Hooke simply says various materials obey this law, metals, wood, stone, baked earths, etc., and recommends the skeptical hearer to try the experiments himself.

Most noteworthy of all is the total want of any recognition of any limit to his law. Apparently he did not carry his experiments far enough to recognize any proportional elastic limit, still less any yield point. Nowhere does he discuss the *strength* of the materials tested. Remember he was interested in watch springs—not in structural members—and that the laws of elastic deflection were of interest to him rather than any measure of elastic strength.

But we should not judge 1678 from the viewpoint of 1928. The omission of tabulated test data in scientific reports was characteristic of Hooke's day. Newton himself records but few test data—none in support of his laws of motion. Experimenters had meager apparatus, very few assistants, and poorly equipped workshops. The technique of observing, recording, and tabulating data had yet to be developed. Moreover, as a recognized part of scientific work, experimentation was still young, and while logical reasoning was subjected to a well-developed technique of criticism, experimental results were apt to be either scornfully disregarded or else accepted with enthusiastic, uncritical faith in their accuracy and significance. Philosophically minded scientists had not learned the great value of experimentation, and experimenters had not learned the fallibility of apparatus, nor the need of tables and graphs of actual test results.

To-day we would by no means accept a proposed law on such a basis of evidence as Hooke offered in 1678, yet we must recognize the fact that the subsequent history of the mechanics of materials has shaken but slightly our faith in its practical reliability—within limits. James Bernoulli in 1705 advanced four fundamental propositions concerning elastic bodies, the third of which stated that stress was *not* proportional to strain, but he presented no experimental evidence, and his statement has not appreciably shaken Hooke's law. The existence of limiting stresses beyond which Hooke's law fails came into gradual recognition, but we still use "*ut tensio sic vis*" for our computations, and then state that the stress must be within the limit. The gradual identification of the limit of Hooke's law with the limit of elastic action would in itself furnish material for a paper. Users of brittle materials, especially cast iron and concrete, soon recognized that Hooke's law was not exact for such materials even for low stresses, and various propositions have been made for replacing Hooke's law for such materials by a parabolic relation—a noteworthy example of such a proposal is found in the classic paper of Talbot on Tests of Reinforced Concrete Beams presented before this Society in 1904. In 1915, Professor E. R. Hedrick, then of the mathematics department of the University of Missouri, made an extensive study of available test data, and suggested that for precise computation Hooke's law might well be modified so that it would be stated that stress was proportional to some power of strain, the index of the power varying for different materials, and being very nearly unity for rolled metals.[1]

No one to day denies the approximate nature of Hooke's law, yet there is no appreciable demand for its abandonment, even by the most exacting of mathematical elasticians; why is it that we do not hear voices demanding that this inexact approximation be discarded and a more precise relation be substituted? For one reason the microscope, especially the metallurgical microscope, and lately the X-ray spectrograph, have led us to believe that materials are far more complex in their structure than the picture of homogeneous, indefinitely divisible stuff, which is the picture on which all our common ideas of elastic solids are founded. So complex seem the relations between crystallin grain and crystallin grain, between laminae or crystallites within the grain, between fiber and fiber of timber, between small masses of regularly arranged atoms, that even the mathematician has not yet developed analyses based on a mathematical relation other than Hooke's law. Then we can quiet our logical consciences by saying that Hooke's law is very close to the truth as a "statistical" law, that is a law which describes the behavior under stress of large numbers of atoms, or crystallites, or grains or fibers, although it may be quite untrustworthy as a predicator of the behavior of any one

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[1] In their book on Applied Elasticity, published in 1926, Timoshenko and Lessells point out that Hedrick's modification would necessitate that for zero strain the ratio of stress to strain (the modulus of elasticity) would become either infinite or zero, which is contrary to experimental observation. They suggest as a more precise relation than Hooke's law:

$$e = \frac{1}{E}(S + kS^2 + k'S^3)$$

in which S denotes the stress, e denotes the strain, and E, k, k', etc. are experimentally determined constants, k being very small, k' still smaller and so on.

grain or crystallite or atom or fiber. Moreover, laws to be widely used must be reasonably simple. If a simple proportion expresses a physical relation fairly well, an exponential relation must express that relation much more precisely before it will supplant the simpler law. Whether we like to admit it or not, the fact remains that even pure scientists seek not merely abstract truth, but truth expressed in workable, even if approximate, formulas.

Moreover, we are becoming rather skeptical of any human statement of physical law as a complete, final, eternal verity. To accept any statement of physical law as a "last word" or an "eternal verity" is a sort of idolatry; rather we are coming to regard all our physical laws as convenient simplified statements which give a useful and workable picture of some phase of the complex happenings in matter and energy. We regard proposed new physical laws as we do proposed A.S.T.M. standards,—presented one year, published as tentative the next, advanced to "standard" a year or two later, and even then always open to revision or abandonment if better standards appear. Viewed in this light Hooke's law is still acceptable to the structural engineer, the machine designer, and the testing engineer.

As is often the case with the formulators of physical laws, Hooke seems to have had no idea of the great importance of his law of springy bodies. He always had his vital interests in apparatus and machines and devices rather than in abstract laws—in his spring watch, his plan for the rebuilding of the burned part of London, in his job as city surveyor to lay out the new city according to the accepted plan drawn up by Sir Christopher Wren. Perhaps the most touching incident of his career came to light after his death. Coin to the amount of some thousands of pounds was found stored in an old chest in his garret, a mute evidence of the constant struggle to lay by a bit for a rainy day, or for old age, and of the daily self denial—the needless self denial as it proved—of the poor little crooked, crabbed, pious genius.

Yet whatever his limitations and his lack of vision, he has left us a great fundamental working rule which has served acceptably for a quarter of a millenium—just about as long as have the laws promulgated by the great Newton. Robert Hooke's thumbmark is on every structural shape and on every stress-carrying forging or casting; it is on every concrete arch and beam, on every timber bent and post. He takes his place among the chemists and the metallurgists and the electricians and the steam engineers who ushered in the mechanical era. And so to-night, after 250 years, we pay our tribute to Robert Hooke, the man who taught us to say "As the stretch, so the force."

ANNUAL REPORT OF THE EXECUTIVE COMMITTEE

The year closing with this annual meeting has been one of gratifying accomplishment in Society affairs. The establishment, beginning January 1, 1928, of a class of membership of companies, firms, corporations, industrial associations and commercial testing laboratories at increased annual dues of $30 has been successfully accomplished, the plan having met with the generous support of nearly 1000 companies and associations. The number of resignations incident to this increase in dues, while not excessive in the light of past experience, together with a decrease in number of new members elected during the year, has resulted in a slight decrease in the membership, which is 4193 as of June 1. A promising start has been made in establishing the new grade of Student Member, with 213 such members enrolled.

The financial condition of the Society is good. The surplus on December 31, 1927, was $40,563.68, an increase during the year of nearly $4300. Investments of Society funds total $28,403.10, including the A.S.T.M. Research Fund of $3246. The budget for 1928 is based on estimated receipts of $121,650, and takes account of the *net* increase in income from dues of company members, estimated at $12,000. Of this sum approximately $5000 has been set aside as a reserve and the balance applied to various expenses, a considerable proportion going towards editorial and publication activities. Thus the endeavor has been made to extend at once the Society's work in promoting and disseminating knowledge of materials by increasing the budget for preprints and Proceedings to enable the Committee on Papers and Publications to accept more technical papers than would otherwise have been possible and to print in full all of the committee reports for the year. The program for this annual meeting is accordingly one of the largest in the Society's history.

Many of the Society's committees have been unusually active and an examination of the committee reports will show much progress in the development of new standards and in the results of investigations. Some important matters of committee organization are under consideration, especially a proposed realignment of committee activities in the non-ferrous metals group. A new standing Committee on Iron-Chromium-Nickel Alloys has been authorized, as well as a new Research Committee on Fatigue of Metals. A special committee on the use of specifications in market quotations is being organized, to study in the beginning specifications for copper alloys in ingot form. The usefulness of specifications in all fields would undoubtedly be enhanced if they were generally made the basis of market quotations. Some questions of committee procedure have been discussed jointly with Committee E-5 on Standing Committees and have led to modifications in the Regulations Governing Standing Committees, which are set forth in detail in the annual report of Committee E-5. An amendment of one section of the By-laws is involved in these modifications and a specific recommendation covering this amendment is included in this report.

Work of the Society's standing and research committees during the year in the carrying on of studies of the properties of materials is set forth in the annual report of Committee E-9 on Correlation of Research. This work, which relates primarily to that purpose of the Society designated in its charter as "promotion of knowledge of materials of engineering," is assuming increasing importance and the annual report of Committee E-9 serves as a useful summary of these activities.

In March of this year there was held in Washington, D. C., the largest of the spring group meetings of committees since this plan was inaugurated four years ago. Twenty-six committees of the Society participated with a registered attendance of 469. Including sub-committees there were approximately 100 meetings held over the three-day period.

The regular publications of the Society for 1927 comprise nearly 4000 pages and exceeded those of all previous years. The triennial edition of the Book of Standards increased over 50 per cent in size between 1924 and 1927. The new plan of distributing the Book of Standards in two parts has been successfully established and it is worthy of special note that 60 per cent of the Society members have subscribed to both parts of the book. A significant development in the special reprinting of committee reports and standards is noted. The publication of a combined index of standards and tentative standards is now under consideration. The annual report of Committee E-6 on Papers and Publications will cover matters relating to the printing of reports and papers for this meeting.

The cooperative relations of the Society with other organizations are always an outstanding feature of its activities. The more important of these relations are enumerated in this report and especially those activities that are being carried on under the procedure of the American Engineering Standards Committee. Recent developments in the simplification and standardization activities of the Department of Commerce have been noted and substantial progress in the translation of A.S.T.M. specifications by the Bureau of Foreign and Domestic Commerce is recorded.

The holding of the Marburg Lecture, to be delivered by Dr. Frank B. Jewett, and the award of the Dudley Medal to Mr. A. V. de Forest, are among the outstanding features of this meeting.

There have been important international developments during the year. Probably of outstanding interest to the Society is the organization of the New International Association for the Testing of Materials, through which it is expected to resume international discussion of tests and properties of materials interrupted by the World War and the formal dissolution in 1923 of the former International Association. Substantial progress has been made in the activities of the International Electrotechnical Commission, the Society being especially interested in the sampling and testing of electrical insulating oils. Discussions have been held relating to a procedure for international standardization, involving the formation of a proposed International Federation of National Standardizing Associations; but the present status of this movement is somewhat in doubt.

Membership:

The membership of the Society on June 1, 1928, was 4193, compared with the membership at the 1927 annual meeting, 4220. Statistics for the year are shown in the following table:

Class of Members	Membership		Losses				Additions		Totals		
	1927 Annual Meeting	June 1, 1928	Resignations	Dropped	Death	Transfer	Transfer	Election	Loss	Gain	Increase
Honorary	5	4	..	..	1	..	..	..	1	..	1[a]
Life or Perpetuity	4143	11	..	..	..	..	1	1	..	2	2
Company, Firm, etc.		1154	119	37	..	381	24	92	537	116	421[a]
Individual, etc.		2972	85	74	20	25	399	218	204	617	413
Junior	68	52	3	10	..	18	..	15	31	15	16[a]
Student	4	....	1	..	..	3	..	..	4	..	4[a]
Total	4220	4193	208	121	21	427	424	326	777	750	27[a]
Student	..	213	..	..	..	..	..	..	..	..	..

[a] Decrease.

The outstanding development in membership matters during the year is, of course, the establishment, in effect, of a class of members comprising companies, firms, corporations, industrial associations and commercial testing laboratories at increased annual dues of $30. This increase of dues was put on an entirely voluntary basis by providing that company members who do not wish to pay the increased dues may still maintain their affiliation with the Society by transferring their membership to an individual, although by so doing they of course lose their official company connection with the Society. The response of the company members has been very gratifying and indeed has exceeded the estimates that were made by the Executive Committee at the beginning of the year. On October 27, 1927, there were 1581 companies, firms, corporations, industrial associations and commercial testing laboratories holding membership who were affected by the provision for increased dues. On June 1, 1928, 986 had retained their status as company members and paid the increased dues; 381 had transferred their membership to individuals and 119 had resigned; leaving 95 who had up to that date not expressed their intention.

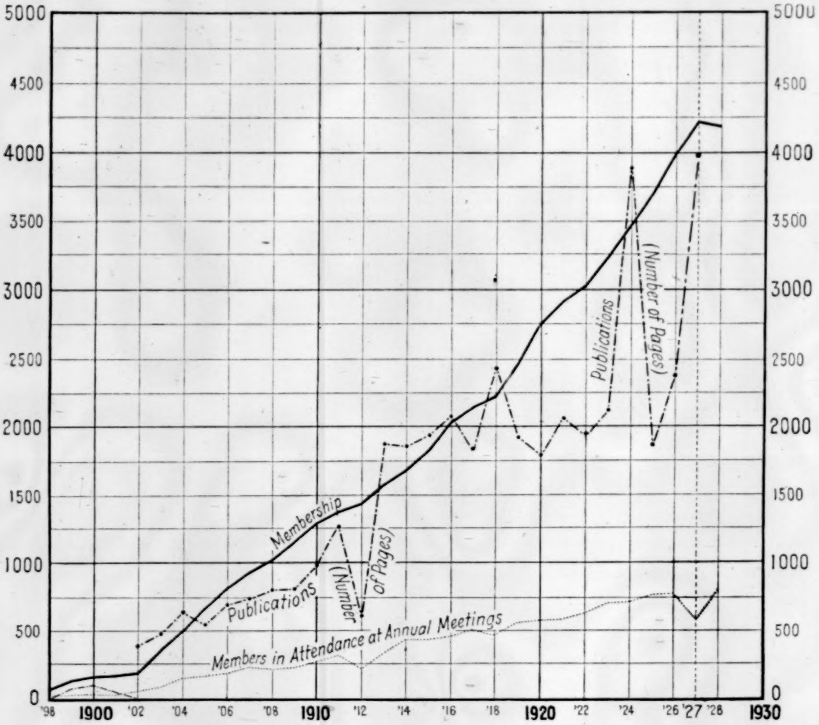

FIG. 1.—Membership and Publication Chart.

The number of resignations has not been considered excessive in the light of past experiences in periods of change in membership dues, although it has been the principal contributing factor in the slight decrease in the total membership of the Society since the last annual meeting.

This decrease in membership is also due to the falling off in the number of new members during 1927, which was 326 compared with 476 reported a year ago and 535 for two years ago. It is believed that this situation is accounted for in part at least by the uncertainty of business conditions that has obtained recently. The establishment of the entrance fee has also had an undoubted influence, although it is expected that the entrance fee will at the same time tend to reduce the percentage of turnover of membership.

A very promising start has been made in the establishment of the new grade of Student Member. This grade of membership was brought to the attention of junior, senior and graduate students in approximately thirty engineering and technical schools through the offices of members of the Society serving on the faculties of those schools. A special booklet was prepared explaining the activities of the Society that would be of particular interest to students. The plan received the hearty support of a number of faculty members, with the result that on June 1 there were 213 student members of the Society. It is felt that the educational features of this plan are of far-reaching importance to the Society and to the profession of materials engineering.

The Society has suffered loss by death of the following members:

	DATE OF MEMBERSHIP		DATE OF MEMBERSHIP
Adams, H. S.	1927	Juneau, C. G.	1921
Baillie, James	1927	Lanza, Gaetano	1899
Beale, H. A., Jr.	1908	Mitchell, J. R.	1914
Cooper, W. A.	1907	Saybolt, E. W.	1926
Dallis, Roy	1914	Scott, H. L.	1915
Davis, B. H.	1915	Spackman, H. S.	1921
de Graaf, G. A.	1922	Stehman, J. V. R.	1922
Fox, E. B.	1920	Titus, Artino	1919
Gates, J. S.	1916	Vaupel, E. A.	1925
Goss, W. F. M.	1896	Wille, H. V.	1898
Gould, W. S.	1908	Wood, C. R.	1924

Many of these members had been active in Society work in one capacity or another for many years. Prof. Gaetano Lanza had been a member since 1899 and an honorary member since 1920. The Executive Committee has adopted the following minute:

GAETANO LANZA

1848–1928

The Executive Committee of the American Society for Testing Materials in meeting April 10, 1928, records with sorrow the death on March 21, 1928, of

Gaetano Lanza, member of the Society since 1899 and honorary member since 1920. Although in failing health since 1914, he continued to be actively interested in the Society's work, serving on its Committee A-1 on Steel and Committee E-1 on Methods of Testing. Of the latter committee he was chairman from 1904 until 1920, and chairman emeritus from 1920 until the time of his death.

Professor Lanza was long associated with the subject of materials testing. After teaching for one year at the University of Virginia, from which he was graduated with honors in 1870, he became an instructor in mathematics at the Massachusetts Institute of Technology. In 1875 he was appointed Professor of Theoretical and Applied Mechanics. He was head of the Department of Mechanical Engineering for twenty-nine years and it was through his untiring efforts that this department reached the high standard that it attained. Professor Lanza established the first laboratory for testing full-size structural timbers and he considered that his best work had been done on full-size specimens for columns and similar structures. He was one of the pioneers in aerodynamic research and in 1910 built a small wind tunnel and carried on investigations of far-reaching importance. Following his retirement from teaching in 1911, after forty-one years of service, he became consulting engineer to the Baldwin Locomotive Works.

He was the author of nearly a hundred technical publications, among his works being "Applied Mechanics" published in 1885 and used as a standard text in many schools and colleges, and "Dynamics of Machinery" which also met with popular favor. He was the recipient of many honors, including a decoration by the King of Italy for his achievements in the engineering field.

He endeared himself to all who knew him by his kindly sympathetic manner. In his death the Society mourns the loss of an eminent engineer, an excellent teacher, and an untiring worker.

RESOLVED, that copies of this minute be sent to his immediate family, the Baldwin Locomotive Works, Massachusetts Institute of Technology and the University of Virginia.

Mr. Beale, Mr. Cooper, Mr. Dallis, Mr. Goss, Mr. Scott, Mr. Spackman and Mr. Wille took a particularly active part in Society affairs. Mr. Goss served as a member of the Executive Committee in 1917–1919, and Mr. Scott in 1923–1925.

A.S.T.M. Committee Activities:

Since the last annual meeting no new standing committees have been organized, so that the number of standing committees remains at 45. The year has witnessed the usual active committee work and 39 of the standing committees are presenting reports to the Society this year. These reports record substantial progress in researches and investigations under way in the committees, and in the promulgation of new and revised standards for materials. The committee reports include 35 new tentative standards, 32 revisions of existing standards, 38 revisions of tentative standards, the advancement of 31 tentative standards to standard, the advancement to standard of 7 tentative revisions of existing standards, and the withdrawal of 5 standards and tentative standards. There are at present 515 standards and tentative standards of the Society, and if the recommendations of the various committees are approved this number will become 548.

Taking favorable action upon a recommendation adopted at the 1927 annual meeting that the Society undertake the development of fire tests of combustible materials, the Executive Committee referred this problem to Committee C-5 on Fire Tests of Materials and Construction. In undertaking this work the committee made suitable additions to its personnel, decided to limit its consideration of the subject for the present to lumber, and has taken the necessary steps to begin its studies of the subject.

The Executive Committee still has under consideration the matter of committee organization within the Society to handle development of standards for clay and cement sewer pipe and drain tile, including the subjects of reinforced concrete culvert pipe and reinforced sewer pipe. Committees C-4 on Clay and Cement-Concrete Pipe and C-6 on Drain Tile are concerned in this matter.

Development of methods for the determination of heat transmission through various types of building material and building constructions was proposed during the year as a desirable activity for the Society to undertake. A study of the matter has brought to light some related activities being undertaken by a committee of the National Research Council and means are being considered of correlating any activities that the Society might undertake in this field with those already under way. The Society's Committee D-9 on Electrical Insulating Materials has for some time been studying the thermal characteristics of certain molded insulating materials, and more recently Committee C-8 on Refractories has initiated a study of the thermal characteristics of refractory materials at the high temperatures to which they are subjected in service.

The Executive Committee has been discussing with Committee B-2 on Non-Ferrous Metals and Alloys certain proposals that this committee has made to transfer certain parts of its work to three new standing committees that would be organized in the non-ferrous metals group of committees for that purpose, continuing the general non-ferrous standardization work in Committee B-2. This suggestion is being carefully studied and it is probable that some action looking towards a realignment of committee activities in the non-ferrous metals group will be taken during the coming year.

Standing Committee on Iron-Chromium Nickel Alloys.—For a year or more the Executive Committee and Committee E-9 on Correlation of Research have been giving thought to steps that the Society might take in the study of the group of corrosion-resistant alloys, of which the alloys of the iron-chromium-nickel system are typical. These alloys lie between the fields of activity being at present developed in Committees A-5 on Corrosion of Iron and Steel and B-3 on Corrosion of Non-Ferrous Metals and Alloys, and it has not seemed desirable to increase the already heavy schedule of investigative work that these committees are undertaking by assigning this group of corrosion-resistant alloys to either committee or dividing the group between them. Nor has it seemed a practical matter to combine the activities of these two corrosion committees. Therefore, acting favorably upon a recommendation of the Joint Advisory Committee on Corrosion, made up of representatives of Committees A-5 and B-3, the Executive Committee has decided to appoint a new standing committee to study various properties, including resistance to corrosion, of the alloys of the iron-chromium-nickel system, and is now considering the best means to initiate this work, bearing in mind its relations to other committee work of the Society.

Research Committee on Fatigue of Metals.—Upon recommendation of the Committee on Correlation of Research, the Executive Committee has authorized the formation of a Research Committee on Fatigue Phenomena in Metals, having the broad functions to conduct, correlate and summarize research in the fatigue of metals, and to report annually to the Society on this subject. Professor H. F. Moore, President of the Society, has been designated as chairman *pro tem* and authorized to take suitable steps to organize the committee. This action has followed the recent decision of the Engineering Division, National Research Council, to discontinue its Committee on Investigation of Fatigue Phenomena of Metals, which had been reached with the understanding that interested technical societies would undertake suitably to correlate and promote research in this field. The decision to form this committee is an important step in carrying forward the policies of the Society in furthering its purpose of promoting knowledge of engineering materials.

Special Committee on Use of Specifications in Market Quotations.—It has been decided to form a special committee of the Society "to study and promote the use of specifications covering copper alloys (in ingot form) as the basis of price quotations in technical and trade journals." This decision has come from consideration of a recommendation made by Committee B-2 on Non-Ferrous Metals and

Alloys, which committee pointed out the lack of definiteness in description of non-ferrous metals and alloys in trade publications in quoting market prices. It is felt that the usefulness of A.S.T.M. specifications in all fields would be greatly enhanced if they were generally made the basis of market quotations and that studies along this line might be productive of plans that would promote the usefulness of the Society's standards. It was decided that preliminary efforts in this direction should be confined to a specific field and that field was selected as copper alloys in ingot form, where there apparently is particular need for greater definiteness in price quotations. The experience gained here will in considerable measure determine the degree to which this work should be extended in other fields. Preliminary steps have been taken towards the formation of the committee under the chairmanship of Past-President G. H. Clamer. The committee will comprise producers and users of the copper alloys concerned and representatives of the technical and trade journals, who have from the beginning shown their interest in and desire to support a study of this kind.

Specifications for Plastering.—During the year Committee C-7 on Lime formally requested permission to proceed with the development of specifications for lime plastering. Specifications of this character necessarily include considerations of design, construction and workmanship that in the opinion of the Executive Committee lie outside the proper field of activity of the Society. In its 1920 annual report[1] the Executive Committee announced a ruling, made in connection with a somewhat similar proposal by Committee C-11 on Gypsum, that considerations relating to application, workmanship, erection and recommended practice should not be included in specifications for gypsum plaster then being offered to the Society. The Executive Committee has reaffirmed the principle upon which the previous ruling was based and has advised the Committee on Lime that the Society on its sole responsibility should not prepare specifications for lime plastering such as are contemplated by the committee. However, the development of inter-society cooperation in the preparation of standards during the past eight or ten years has been such as to offer the possibility of the development of specifications of this character by suitably constituted joint committees upon which duly appointed representatives of interested societies and organizations would serve, and the Executive Committee expressed its willingness to cooperate with other organizations in the preparation of specifications for lime plastering.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. XX, Part I, pp. 59–62 (1920).

This decision was communicated to the Committee on Lime and also to the Committees on Gypsum, on Cement and on Concrete, the latter committees being interested in the development of specifications for gypsum plastering and cement plastering. This has led to study being given to the formation of a Joint Committee on Plastering Specifications covering the several types of plastering, and this possibility is being considered in the several interested committees and in the industries immediately concerned.

Committee Procedure.—The Executive Committee, acting jointly with Committee E-5 on Standing Committees, has made several modifications in the Regulations Governing Standing Committees which are reported in detail in the current annual report of Committee E-5. These modifications relate principally to (1) membership on standing committees both on the part of individuals and on the part of companies, firms, corporations and associations; (2) the classification by producers, consumers and general interests of votes of standing committees on matters affecting standards in cases where substantial negative vote on letter ballot, construed as ten per cent of the affirmative and negative votes, has developed; (3) certain provisions respecting the form of letter ballot votes and the requirements governing voting of committee members on reports as a whole; and (4) a modification of the procedure at annual meetings governing the action of the Society on proposed revisions of standards and tentative standards that have not received the required two-thirds vote by letter ballot of the responsible standing committee.

Revisions of the kind referred to in item (4) originate either in the responsible committees after their letter ballots have been conducted (that is, usually at meetings of the committee held during the annual meeting of the Society) or independently of the committee on the floor of the annual meeting. (Past experience has indicated that in a great majority of cases these revisions are brought to the Society by the committees themselves.) The consideration given to this matter by the Executive Committee and Committee E-5 has made it seem desirable that approval of revisions of this character by the Society shall be contingent upon subsequent approval by letter ballot vote of the standing committee concerned; with the further provision that if the modifications thus referred to a subsequent letter ballot vote of the committee fail of approval, the original recommendations of the committee shall prevail and the proposed modifications be referred to the committee for study and report at the next annual meeting. It is to be understood that corrections and modifications that may fairly be construed as editorial in character are not to be included in this provision. Amendment of Article VI, Section 1, of the By-laws dealing with "Procedure Governing the Adoption of Standards" is required to put this provision into effect.

Proposed Amendment of the By-laws:

To accomplish the purposes outlined in the foregoing paragraph, the Executive Committee proposes the following amendment of the By-laws:

Amend Article VI, Section 1, of the By-laws by inserting the following paragraph between the third and fourth paragraphs of the present section:

> Approval of modifications proposed on the floor of the annual meeting, of recommendations approved by the required letter ballot vote of the appropriate standing committee affecting standards and tentative standards, shall be contingent upon subsequent approval of such proposed modifications by letter ballot vote of the standing committee concerned; provided that if such proposed modifications fail of such subsequent approval, the original recommendations of the committee shall prevail and the proposed modifications be referred to the committee for study and report at the next annual meeting.

As required by the By-laws, this proposed amendment was announced to the membership prior to the annual meeting in Circular to Members No. 195 dated May 22; and the Executive Committee recommends that the amendment be referred to letter ballot of the Society.

Publications:

The regular publications during 1927 were the Proceedings, the triennial Book of A.S.T.M. Standards and the Year Book. A comparative statement of the volume of regular publications during the past four years is as follows:

	1924, PAGES	1925, PAGES	1926, PAGES	1927, PAGES
Proceedings	2306	1416	1895	1706
Book of A.S.T.M. Standards	1219	....	....	1871
Supplement to Book of Standards	....	117	102	....
Year Book (Membership List)	328	352	374	398
	3853	1885	2371	3975

The volume of regular Society publications over the past twenty-five years is recorded graphically in Fig. 1. It will be seen that 1927 has eclipsed all previous years.

It is of particular interest to note that the Book of Standards increased slightly over 50 per cent in size between the 1924 and 1927 editions. With the 1927 edition the Book of Standards was published for the first time in two parts, Part I covering Metals and Part II covering Non-Metals. Members are furnished on their membership with either one of these parts together with the supplements thereto issued between the years of publication of the triennial book; and members desiring both parts pay the sum of $2 triennially in addition to their dues. It is significant to record that 2519 members, or 60 per cent of the total membership, have subscribed to both parts of the Book of Standards.

In addition to the regular publications the Society published in 1927 the Book of A.S.T.M. Tentative Standards (825 pp.), which is furnished to members on order at special prices. This brings the total number of pages of bound publications issued since the last annual meeting, but not including preprints and reprints, up to 4800.

Special Reprints of Committee Reports.—Reprints of several committee reports were published for committee use and for sale, the principal ones being the report of Committee A-5 on Corrosion of Iron and Steel, 72 pp. (2000 copies); report of Committee D-2 on Petroleum Products and Lubricants, with all the standards and tentative standards that it has promulgated, 245 pp. (1800 copies); report of Committee D-9 on Electrical Insulating Materials, with all the standards and tentative standards that it has promulgated, 132 pp. (500 copies); and A.S.T.M. Specifications and Methods of Test for Textile Materials prepared by Committee D-13, 107 pp. (1500 copies). The reprinting of these reports and standards has proved useful to the members of the particular standing committees and has served effectively to disseminate these standards throughout the interested industries. The Executive Committee has endorsed the policy established by the Committee on Papers and Publications of issuing such reprints upon the request of any standing committee that is prepared to underwrite the cost of the pamphlets, as has been done in the cases mentioned.

A.S.T.M. Bulletin.—The year 1927 was the first in which the Bulletin was published bi-monthly. The six Bulletins for that year comprised 58 pages of text matter, comprising appropriate announcement of general Society affairs, committee activities, cooperative relations with other organizations, and other matters of interest to the members. The income from advertising in the Bulletin has put the Bulletin practically on a self-sustaining basis. Thus the six issues of the Bulletin in 1927 cost $4036.03, including mailing charges but exclusive of overhead expenses, while the income from advertising was $3896.00, leaving a net cost of about $140.

The Bulletins for 1928 have been planned along the same lines. The January issue was again devoted to a review of the Society's accomplishments for the preceding year and has come to have particular value as a review number, receiving considerable notice in the technical and trade press. In fact, the establishment of the Bulletin on this more substantial basis has been of particular value in giving desirable publicity to Society activities in the technical and trade journals throughout the year.

Combined Index of Standards and Tentative Standards.—Mention was made in the report a year ago that consideration was being given to the possibility of issuing a suitably combined index of the standards and tentative standards of the Society, with the thought that the distribution of such an index among particularly the users of materials might effectively bring to their attention the availability of A.S.T.M. specifications in the purchase of materials. This suggestion has been made in line with discussion of ways and means of promoting the usefulness of the Society's work. The proposal has since been studied by the Committee on Papers and Publications, who have recommended the publication of such a combined index to be issued annually to the members in the belief that it will be of decided value in facilitating reference to the constantly growing volume of standards and tentative standards. The Executive Committee has endorsed this recommendation in principle and is considering the financial problems that are involved.

Finances of the Society:

Report for Fiscal Year 1927.—The annual statement of the finances of the Society follows in the report of the auditors for the fiscal year January 1, 1927, to December 31, 1927.

The surplus on December 31, 1927, was $40,563.68, including the life membership fund of $1805.20, an increase for the year of $4268.02. A comparison of the financial condition of the Society at the close of the past five fiscal years is given at the end of the report. The surplus includes investments totalling $28,403.10.

The report lists the funds held to the account of committees of the Society and gives also the statement of the Dudley Medal and Marburg Lecture Fund. Investments of Society and other funds are listed.

It will be noted that the A.S.T.M. Research Fund now amounts to $3246. Under the policy adopted there is to be added to the Fund each year not less than half of the sum received from entrance fees.

REPORT OF THE AUDITORS FOR THE FISCAL YEAR JANUARY 1, 1927, TO DECEMBER 31, 1927

JOHN HEINS AND CO.
CERTIFIED PUBLIC ACCOUNTANTS

PHILADELPHIA, January 7, 1928

AMERICAN SOCIETY FOR TESTING MATERIALS,
MR. C. L. WARWICK, *Secretary-Treasurer*,
Philadelphia, Pa.

Dear Sirs:

We respectfully report that we have made an audit and examination of the books and accounts of your Society for the seven months ended December 31, 1927, having previously made a similar audit and report for the preceding five months ended May 31, 1927, and at both audits found the accounts to be correct and to be in their usual excellent condition.

We submit balance sheet as of December 31, 1927, as also a statement of cash receipts and disbursements for the twelve months then ended.

We have verified the transactions set forth in the budget record for the last seven months as also for the five months ended May 31, last, as reported in ours of June 11, last, and found the same to be correct.

We have verified by actual inspection and count the securities as scheduled under Investments.

Respectfully submitted,
(Signed) JOHN HEINS AND CO.

BALANCE SHEET AS OF DECEMBER 31, 1927

ASSETS			
Current Funds		$1,594.65	
Investments General		25,157.10	
Investments—A.S.T.M. Research Fund		3,246.00	
Accounts Receivable:			
For Publications and Advertising	$4,797.85		
Members for 1926 Dues	2,594.08		
Members for Binding	70.00		
		$7,461.93	
Furniture and Fixtures		5,023.49	
			$42,483.17
LIABILITIES			
Publications and advertising paid for in advance	$162.47		
Members dues paid in advance	1,414.02		
Members binding paid in advance	43.00		
Entrance Fees paid in advance	300.00		
		$1,919.49	
Life Membership Fund	$1,805.20		
Surplus	38,758.48		
		$40,563.68	
			$42,483.17

RECEIPTS AND DISBURSEMENTS

JANUARY 1, 1927, TO DECEMBER 31, 1927

Current Funds, January 1, 1927			**$6,810.58**

RECEIPTS

Current Dues	**$60.661.11**		
Past Dues	802.50		
Advance Dues	1,390.72		
Current Entrance Fees	3,353.00		
Advance Entrance Fees	300.00		
Total Dues		$66,507.33	
Sale of Publications:			
Separate Standards	$4,331.49		
Book of Standards	4,768.46		
Book of Standards—Members for both parts	4,373.02		
Book of Tentative Standards	7,091.09		
Proceedings	3,975.36		
Index to Vols. 21–25	1,107.69		
Miscellaneous (including special reprints)	6,814.72		
Total Sale of Publications		32,461.83	
Binding (Members)		1,047.92	
Advertising in Bulletin		3,301.25	
Authors' Reprints		199.30	
Sale of Certificates of Membership		40.00	
Interest on deposits and investments		3,173.80	
Income A.S.T.M. Research Fund		46.50	
Accrued interest and premium		119.63	
Excess remittances		190.36	
Investments matured or sold		35,782.19	
Registration and other fees, Annual Meeting		1,485.00	
Miscellaneous		15.95	
Total Receipts			$144,371.06
Carried forward			$151,181.64

Brought forward			$151,181.64

DISBURSEMENTS

Publications:			
Year Book	$3,780.68		
Proceedings	24,757.92		
Book of Standards	18,136.97		
Book of Tentative Standards	3,383.14		
Preprints	3,813.67		
Bulletins and Circulars to Members	5,492.67		
Separate Standards	2,454.57		
Index to Proceedings (Vols. 21-25)	1,797.90		
Miscellaneous (including special reprints)	4,463.03		
		$68,080.55	
Salaries		$31,530.46	
General Office Expenses		6,184.60	
Expenses, Standing Committees		1,738.23	
Expenses, Annual Meeting		3,032.02	
Traveling Expenses—Executive, Nominating, Correlation of Research and Promotion of Usefulness Committees		1,125.09	
Rent and insurance, storage rooms		321.00	
Rent, headquarters		2,400.00	
Headquarters maintenance		393.56	
Furniture and Fixtures		1,828.57	
Certificates of Membership		9.00	
Investments A.S.T.M. Research Fund		2,164.00	
A.S.T.M. Research Fund		50.00	
American Engineering Standards Committee		1,905.09	
U. S. National Committee, International Electrotechnical Commission		250.00	
Annual Tables of Constants and Numerical Data		100.00	
Investments		28,120.25	
Accrued interest and premium		119.63	
Refund of excess remittances		190.36	
Miscellaneous		44.58	
Total Disbursements			$149,586.99
Balance, Current Funds, December 31, 1927			$1,594.65[a]

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[a] Balance accounted for as follows:

Cash on hand	$3,346.65	
Liberty bonds ($4,000) and Chesapeake & Ohio R. R. bonds ($10,000) carried as Current Funds	14,000.00	
	$17,346.65	
Less checks drawn but not paid against cost of Proceedings	15,752.00	
		$1,594.65

MISCELLANEOUS FUNDS

In addition to the regular Society funds the Secretary-Treasurer has on hand the **following funds, partly invested as shown:**

Committee A-1 on Steel	$202.71	
Committee A-5 on Corrosion of Iron and Steel	8,979.01	
Committee B-2 on Non-Ferrous Metals and Alloys	50.00	
Committee C-1 on Cement	778.00	
Committee C-9 on Concrete and Concrete Aggregates	637.62	
Committee C-10 on Hollow Masonry Building Units	219.29	
Committee D-1 on Preservative Coatings	28.97	
Committee D-14 on Screen Wire Cloth	59.25	
Committee D-18 on Natural Building Stones	250.20	
Joint Committee on Investigation of Phosphorus and Sulfur **in Steel**	112.62	
A.E.S.C. Sectional Committee on Cast Iron Pipe	2,555.02	
Total Committee Funds		$13,872.69

DUDLEY MEDAL AND MARBURG LECTURE FUND

Cash balance, January 1, 1927		$1,449.14	
RECEIPTS			
Contributions	$3.00		
Interest on Deposits and Investments	394.51		
Total Receipts		397.51	
			$1,846.65
DISBURSEMENTS			
Cost of Die for Medal	$450.00		
Cost of 1927 Medal	90.00		
Honorarium, 1927 Lecturer	200.00		
Engrossing 1927 Lecture Certificate	3.25		
Printing	15.00		
Investments	550.00		
Accrued Interest	3.99		
Total Disbursements,		$1,312.24	
Cash balance, December 31, 1927		$534.41	

INVESTMENTS

SOCIETY FUNDS

General:

$17,400	U. S. Liberty Bonds 4th 4¼'s due 1938	$16,936.58	
2,000	Penna. R. R. Second 5's due 1964 held for Life Membership	2,000.00	
3,000	Penna. R. R. Equipment Bonds 6's due 1933	3,052.56	
2,000	Michigan Central Equipment Bonds 6's due 1932	2,085.96	
1,000	Balt. & Ohio R. R. Refunding & General Bonds 6's due 1995	1,082.00	
		$25,157.10	

A.S.T.M. Research Fund:

3,000	Balt. & Ohio R. R. Refunding & General Bonds 6's due 1995	3,246.00	
			$28,403.10

DUDLEY MEDAL AND MARBURG LECTURE FUND

$6,500	Balt. & Ohio R. R. Refunding & General Bonds 6's due 1995	$6,977.50

COMMITTEE FUNDS

$8,600 U. S. Liberty Bonds 4th 4¼'s due 1938:

Committee A-5	$8,259.95	
Committee C-1	509.53	
		$8,769.48

FINANCIAL CONDITION AT CLOSE OF FISCAL YEARS 1923–1927, INCLUSIVE

Fiscal Year	Assets					Liabilities		
	Current Funds	Investment	Accounts Receivable	Furniture and Fixtures	Total	Accounts Payable[a]	Reserve for Publications	Surplus and Life Membership Fund
1923	**$5 139.72**	**$23 660.65**	**$5 202.16**	**$3 598.49**	**$37 601.02**	**$467.99**	**$6 894.61**	**$30 238.42**
1924	282.06	19 845.44	6 909.42	3 672.90	30 709.82	4 797.31	495.94	25 416.57
1925	5 041.21	24 023.60	3 946.20	3 808.45	36 819.46	1 036.92	4 368.37	31 414.17
1926	6 810.58	33 196.26	4 905.90	3 753.09	48 665.83	1 249.01	11 121.16	36 295.66
1927	1 594.65	28 403.10	7 461.93	5 023.49	42 483.17	1 919.49	....	40 563.68

[a] These sums represent dues and publications paid in advance and do not include any unpaid bills except for 1924, a loan of $4000 from the Girard Trust Co.

In the foregoing financial statement no account has been taken of the assets of the Society in the form of publications in stock. The inventory on May 25, 1928, may be summarized as follows:

	NUMBER OF COPIES
Proceedings	5,185
Index to Proceedings (Vols. I–XII, incl.)	530
(Vols. XIII–XX, incl.)	695
(Vols. 21–25, incl.)	675
Book of A.S.T.M. Standards (Part I, Metals)	1,570
(Part II, Non-Metals)	1,460
Reprints of 340 Standards	20,000 (approx.)
Special reprints for general sale	4,500 (approx.)

1928 Finances.—The Society's activities for the current year have been based upon a budget that anticipates total receipts of $121,650, of which $83,500 are estimated from dues and entrance fees, $28,900 from sales of publications and $9250 from a number of miscellaneous items, including advertising in the Bulletin, registration fees at annual meeting and interest on deposits and investments. The preparation of the budget for 1928 presented an interesting problem because of the relative uncertainty of the sum that would be available from increased dues of company members. The budget was based on the expectation of having at least 950 company members by the close of the year and a net growth in membership at least equal to that of 1927. The former expectation has already been realized and there will probably be over 1050 company members in good standing at the close of the year. However, the growth in membership so far this year has been somewhat less than for 1927.

Making due allowance for losses in membership that are to be expected during a period of adjustment of membership dues, it has been estimated that the *net* increased income this year from dues of company members will be approximately $12,000. The Executive Committee has allocated this estimated income approximately as follows: $2000 has been added to the sums normally available for Proceedings and Book of Standards; about $3000 has been applied in salaries of a technical assistant and additional clerical assistance; about $2000 has been applied to offset the loss in income for the past year or so occasioned by the falling off in new members; and the remaining $5000 has been assigned to a reserve fund, which will be set up only if the income from current dues permits, which now seems probable. This reserve will be applied in part to publication expenses if necessary, but it is designed more particularly as a contingent fund against possible expense in connection with rental of headquarters at the expiration of the present lease.

Attention is called to the fact, reported upon in further detail in the report of Committee E-6 on Papers and Publications, that the number of papers presented at this meeting is nearly 50 per cent greater than last year and in fact is larger than in any year in the history of the Society. This has been made possible by the support afforded by increased dues of company members and is of significant value in the work of the Society in promoting and disseminating knowledge of materials.

Society Headquarters:

As mentioned in the annual report a year ago, the lease upon the quarters now occupied by the Society in the Engineers' Club of Philadelphia expires at the close of 1929. The Executive Committee is discussing with the officers of the Club the possibility of a renewal of the lease, involving the procurement of additional space to meet the needs imposed by the estimated growth of the Society and its activities within the next five or ten years. Consideration is also being given to other possibilities for the establishment of Society headquarters in the event that it may prove necessary to make some change in present arrangements.

Edgar Marburg Lecturer for 1928:

Upon the recommendation of the Edgar Marburg Lecture Committee, consisting of J. H. Gibboney, chairman, G. H. Clamer and A. N. Johnson, the Executive Committee has invited Dr. Frank B. Jewett, President, Bell Telephone Laboratories and Vice-President, American Telephone and Telegraph Co., to deliver the third Edgar Marburg Lecture during the coming annual meeting. Doctor Jewett will speak on "Some Research Problems Involved in Transoceanic Telephony."

Award of the Charles B. Dudley Medal for 1928:

Upon the unanimous recommendation of the Committee on Medal Award, consisting of Zay Jeffries, chairman, P. J. Freeman and J. H. Hall, the Executive Committee has awarded the second Charles B. Dudley Medal to A. V. de Forest, Research Engineer, American Chain Co., Inc., Bridgeport, Conn., for his paper on "A Method of Graphic Representation of Magnetic Characteristics" presented at the annual meeting of the Society a year ago. The formal award of the Medal is to be made immediately following the delivery of the Marburg Lecture.

The New International Association for the Testing of Materials:

During the year an important step forward in international consideration of engineering materials was taken in the decision reached by the delegates to the International Congress for Testing Materials held in September, 1927, at Amsterdam, to organize a New International Association for the Testing of Materials. In the A.S.T.M. Bulletin for November, 1927, there appeared a full account of the activities of the Congress, to which the Society sent as its formal delegates Past-President W. H. Fulweiler and Vice-President T. D. Lynch. In all there were thirty-two delegates representing seventeen nations, who considered at length the resumption of international discussion of materials that had been interrupted by the World War and the formal dissolution in 1923 of the old International Association for Testing Materials. In the beginning there were differences of opinion among the delegates, some feeling that the international association should be reorganized in its old form; others believing that no attempt should be made to organize a formal society but that international congresses held periodically would suffice. Similarly, there was some difference of opinion as to whether work in standardization of materials should be attempted. It was finally concluded that some form of international organization is desirable and the plenary session of the Congress adopted a proposed Constitution of an organization to be designated "The New International Association for the Testing of Materials." Its objects, as quoted from Section 2 of the Constitution, are:

> The objects of the New Association shall be to secure international cooperation, exchange of views, experience and knowledge in regard to all matters connected with the Testing of Materials. The principal means of securing this result is to be the holding of periodical International Congresses at intervals of not less than three nor more than five years, so far as circumstances permit. The New Association shall, however, be free to adopt other additional methods of securing and maintaining international contact as circumstances may suggest. Questions of standardization of materials are to be regarded as being outside the scope of the Association.

In their report to the Executive Committee the Society's delegates formally offered the Constitution of the New Association for approval, recommending that the Executive Committee ratify this Constitution and join with other testing materials bodies throughout the world in the accomplishment of the objects for which the New Association stands.

The Executive Committee has formally approved the Constitution and has endorsed the objects for which the New International

Association has been formed. Suitable steps were taken in conjunction with the publication of the March, 1928, Bulletin to bring this matter favorably to the attention of the members of the Society, who under the plan of membership in the N.I.A.T.M. are by virtue of this A.S.T.M. membership eligible either as individuals or companies to membership in the International Association. Up to June 1, 112 individuals and 22 companies have qualified for membership in the International Association.

The Executive Committee has appointed Past-President W. H. Fulweiler to serve as American member on the Permanent Committee of the N.I.A.T.M., which is the governing body of the Association and consists of one member from each country having at least twenty members in the Association. The Permanent Committee has started work on plans for the next International Congress, which will be held in Zurich in 1931. The activities of the Association have been divided into four groups, as follows:

Group A—Metals.
Group B—Non-metallurgical Inorganic Materials.
Group C—Organic Materials.
Group D—Questions of General Importance.

On the whole, considering the experience of the former International Association in its efforts to write international standard specifications for materials, it has seemed wise that the attempt to develop such specifications (which necessarily involve economic and indeed political considerations) through the New International Association should not be made. This is not understood, however, to exclude the consideration of international standard *methods of tests* for materials; and it is expected that the Society will propose for discussion at the 1931 Congress some topics that may lead to international consideration of test methods.

It is planned to keep the members of the Society informed of activities in the New International Association through appropriate notices in the Bulletin, and the Constitution and other pertinent information regarding the Association will appear annually in the Year Book.

U. S. National Committee, International Electrotechnical Commission:

Discussion of the sampling and testing of electrical insulating oils has been the chief topic in the International Electrotechnical Commission in which the Society has been interested. One of the Society's representatives on the U. S. National Committee, E. A. Snyder, has served as chairman of the committee of advisers on this subject. At the meeting of the International Commission in Italy last fall an international method of sampling insulating oils was proposed based very largely upon the Society's Standard Method of Testing Electrical Insulating Oils (D 117 – 27), some changes having been made in order to make the method better applicable to European practice. A formal report on this matter prepared by the U. S. National Committee has been referred to Committees D-9 on Electrical Insulating Materials and D-2 on Petroleum Products and Lubricants for their consideration and comment to the U. S. National Committee. The I.E.C. committee is studying the flash point, pour point, neutralization number and mineral acid tests, the appropriate A.S.T.M. methods being reviewed in that connection. Research work on a broad international scale is being undertaken on the sludging properties of oils; and it is becoming evident that work of this character will ultimately have a far-reaching effect in promoting international accord and understanding in the use of this important electrical material. Progress, necessarily slow, is being made in which the Society is taking an active and important part.

The Executive Committee has felt that the interests of the Society in the work of the I.E.C. justified a modest increase in the financial contribution towards the expenses of the U. S. National Committee and has increased the contribution from $250 to $300 for 1928.

International Standardization:

In its report to the Society a year ago[1] the Executive Committee set forth the status at that time of discussions that were taking place respecting the development of procedure for international engineering standardization. A proposal to form an international standards association, made up of the respective national standardizing bodies (in this country the American Engineering Standards Committee) was then under consideration and the views of the Society as expressed in a communication from the Executive Committee to the A.E.S.C. were summarized in the 1927 report. Concurrent with this proposal, and in fact growing out of it, was a proposal that the International Electrotechnical Commission might be suitably expanded to function internationally in engineering standardization along lines that it has pursued in the field of electrical standardization. Involved in these two proposals was the suggestion that the interests of the American Engineering Standards Committee and the U. S. National Committee of the I.E.C. in international technical matters might be suitably consolidated for the purpose of American representation in whatever international standardization body might ultimately be set up. A plan for expanding the U. S. National Committee of the I.E.C. had been proposed.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, pp. 93–95 (1927).

Consideration of these matters has gone forward during the year, with which the Society has been in more or less close touch. Two developments may be recorded: First, it has been agreed that the International Electrotechnical Commission will not expand its field and will continue its standardization activities in electrotechnical matters, in which it is recognized as the authoritative international body. It will cooperate where necessary with other international bodies dealing with standardization matters. The proposed expansion of the U. S. National Committee of the I.E.C. has not been further considered. Secondly, the *interim* international committee formed to bring about the formal organization of an International Federation of National Standardizing Associations (I.S.A.), along the general lines originally contemplated and mentioned in last year's report, has formally laid the articles of constitution and a plan for preliminary organization before the national standardizing bodies of the world. Up to June 1, eleven of these national standardizing bodies (principally among the continental European nations) had indicated their willingness to become members of the I.S.A. The American Engineering Standards Committee has not yet made a decision, and the Executive Committee is informed that the British Engineering Standards Association has decided that it will be unable to become a member of the I.S.A. The withdrawal of the British, from whom the original suggestion for the formal international federation had emanated, has left the present status of this movement somewhat in doubt. Recent advices indicate that consideration is being given by the countries of continental Europe to an organization of less formal character.

Pending further development and formation of suitable agencies for bringing about international cooperation in standardization activities, the Executive Committee will handle matters relating to international discussion of materials standards through whatever channels seem best suited to the purpose. In matters of general standardization, the Society looks to the American Engineering Standards Committee as a clearing-house, since that committee is in formal touch with the national standardizing bodies of the world. It is believed that the New International Association for the Testing of Materials is a logical medium for the international consideration of tests and properties of materials.

International Discussion of Road Materials Definitions:

Early in 1928 the Society received through the American Engineering Standards Committee an invitation from the British Engineering Standards Association to discuss with them certain definitions of terms relating to bituminous road materials that had been drafted by a committee of the International Roads Congress. The Executive Committee consulted with Committee D-4 on Road and Paving Materials, the committee responsible for A.S.T.M. definitions for bituminous road materials; also with officials of the U. S. Bureau of Public Roads, through whom formal American participation in the activities of the International Roads Congress is effected. It was decided to accept the invitation and Mr. Prévost Hubbard, secretary of Committee D-4, was appointed as the representative of the Society to discuss these definitions with the British. These discussions have been held and the Executive Committee will receive and consider Mr. Hubbard's report and recommendations.

American Engineering Standards Committee:

During the past year the American Engineering Standards Committee has extensively revised its Rules of Procedure to make them sufficiently flexible to fit all of the varied conditions that are met with in the wide range of industrial subjects covered by A.E.S.C. activities. Experience has indicated the necessity for recognizing different methods of formulating standards to fit different conditions. The methods now recognized are founded on the principle that the basic test to be applied in all cases is the fact of the assent, affirmatively expressed, of the groups having substantial interest in a proposed standard. Such groups are to have an inherent right to representation on the committee or other body dealing with the subject matter of the standard, but it is not essential that this right be exercised.

The principal change in procedure in which the Society is interested is that which recognizes so-called "proprietary" standards, that is, standards developed by technical societies and similar bodies having the making and promulgation of standards as a specific function. Under this revised procedure such "proprietary" standards may be offered for approval and subsequently revised within the procedure set up by the sponsor body, on the condition that it will be shown that the standard is acceptable to the various groups that are concerned with it. This method is particularly applicable to highly specialized fields in which the standard developed by an organization functioning in that field has already achieved a position of recognized eminence.

The Society is sponsor or joint sponsor for a number of projects that have been assigned to sectional committees, which are listed in the current Year Book. It is also represented upon a number of sectional committees sponsored by other organizations, which are also listed in the Year Book. In the following paragraphs are given brief comments upon the principal developments that have taken place during the year in A.E.S.C. projects with which the Society is connected.

Methods of Testing Timber.—As the result of action taken at the last annual meeting, the U. S. Forest Service and the Society as joint sponsors offered the A.S.T.M. Standard Methods of Testing Small Clear Specimens of Timber (D 143 - 27) and Standard Methods for Conducting Static Tests of Timbers in Structural Sizes (D 198 - 27) to the A.E.S.C. for approval as American Standard. The methods have now been formally approved as American Standard.

Specifications for Cement.—As reported a year ago, favorable action had been taken by the Society upon the report of the Sectional Committee on Cement recommending approval of the A.S.T.M. Standard Specifications and Tests for Portland Cement as American Standard. Favorable action has since been taken by the A.E.S.C. on this recommendation and a formal letter ballot in accordance with its procedure is being conducted.

Specifications for Copper Wire.—During the year the sectional committee on this subject, the personnel of which is coincident with that of the Society's Committee B-1 on Copper Wire, recommended that the A.S.T.M. Specifications for Soft or Annealed Copper Wire (B 3 - 27) and Specifications for Tinned Soft or Annealed Copper Wire for Rubber Insulation (B 33 - 21) be approved by the A.E.S.C. as American Standard. The former of these specifications had previously been approved as Tentative American Standard and only slight modifications had been made. These two specifications had been adopted in substance, and with a few minor exceptions in wording also, by the Sectional Committee on Insulated Wire and Cable as component parts of comprehensive wire and cable specifications. This recommendation has been approved by the A.E.S.C. and a formal letter ballot in accordance with its procedure is being conducted.

This sectional committee is recommending at this meeting that the Society's Specifications for Hard-Drawn Copper Wire (B 1 - 27) be offered to the A.E.S.C. for approval as American Standard. The action of the annual meeting on this recommendation will determine the subsequent steps that will be taken by the Society as sponsor.

Insulated Wire and Cable.—The Sectional Committee on Insulated Wire and Cable, of which the Society is one of the sponsors, has completed certain portions of its work and those portions of direct interest to the Society have been approved for submission to A.E.S.C. These include Specifications for Soft Copper Wire and Tinned Wire for Rubber Insulation mentioned in the preceding section and Specifications for 30-per-cent Rubber Insulation for Wire and Cable for General Purposes, which have in general been based upon the A.S.T.M. Specifications for Insulated Wire and Cable: 30-per-cent Hevea Rubber (D 27 - 21 T). Committee D-11 on Rubber Products, in charge of the latter specifications, is proposing revisions of these specifications as agreed upon in the sectional committee discussions.

Petroleum Products and Lubricants.—The Sectional Committee on Methods of Testing Petroleum Products and Lubricants, the personnel of which is coincident with that of Committee D-2 of the Society, presented a report during the year recommending that sixteen A.S.T.M. methods be approved as American Standard and three as Tentative American Standard. Subsequently three of the methods were temporarily withdrawn from the list pending the possibility of slight revisions being made at the coming annual meeting and the remaining methods, as follows, have been approved by A.E.S.C. action:

As American Standard:

Abridged Volume Correction Table for Petroleum Oils (D 206 - 25).
Analysis of Grease (D 128 - 27).
Burning Quality of Kerosine Oil (D 187 - 27)
Burning Quality of Long Time Burning Oil for Railways (D 219 - 27).
Burning Quality of Mineral Seal Oil (D 239 - 27).
Distillation of Gasoline, Naphtha, Kerosine and Similar Petroleum Products (D 86 - 27).
Distillation of Natural Gas Gasoline (D 216 - 27).
Flash Point by Means of Pensky-Martens Closed Tester (D 93 - 22).
Flash and Fire Points by Means of Open Cup (D 92 - 24).
Melting Point of Paraffin Wax (D 87 - 22).
Sulfur in Petroleum Oils Heavier than Illuminating Oils (D 129 - 27)
Thermal Value of Fuel Oil (D 240 - 27).
Viscosity of Petroleum Products and Lubricants (D 88 - 26).

As Tentative American Standard:

Cloud and Pour Points of Petroleum Products (D 97 - 27 T).
Neutralization Number of Petroleum Products (D 188 - 27 T).
Penetration of Grease and Petrolatum (D 217 - 27 T).

Specifications for Rubber-Lined Fire Hose.—The Sectional Committee on Specifications for Rubber-Lined Fire Hose has completed its work on the problem assigned to it, namely, the development of standards of construction and performance under test of rubber-lined fire hose for use by private and public fire departments, and has harmonized the requirements of various specifications for this product that are in use to-day. The sectional committee has presented a report with specifications to the two sponsor bodies, the A.E.S.C. Fire Protection Group and the A.S.T.M. The Executive Committee has referred this report to Committee D-11 on Rubber Products with the request that the committee present recommendations to the Society at this annual meeting. It is desired as a matter of policy that the new specifications proposed by the sectional committee shall ultimately replace the two present A.S.T.M. specifications for fire hose, upon which the new specifications have been substantially based. The action at the annual meeting will largely determine the nature of the report from the A.S.T.M. to the A.E.S.C. as co-sponsor for this project.

Zinc Coating of Iron and Steel.—The Sectional Committee on Zinc Coating of Iron and Steel has made substantial progress in its work; and in its report this year to the Society as sponsor it is recommending two specifications for approval by the Society, namely, Specifications for the Zinc Coating on Iron and Steel Sheets and Specifications for Zinc (Hot-Galvanized) Coatings on Structural Steel Shapes, Plates and Bars and Their Products. The first of these is identical with those portions of the Society's Standard Specifications for Zinc-Coated (Galvanized) Sheets (A 93 – 27) relating to coatings. The sectional committee is reporting progress in other lines of its work.

Classification of Coal.—The sectional committee on this subject was organized under the sponsorship of the Society in June of last year; too late, however, to carry specific mention in last year's annual report. An account of the organization meeting was given in detail in the July, 1927, Bulletin. The Society's representative on the committee is A. C. Fieldner, who was elected chairman. The activities of the committee have been divided into three major groups, namely, scientific classification, use classification and marketing practice. Good progress has been made during the year on all three sub-divisions of the work.

Sectional Committee on Methods of Test of Road and Paving Materials.—The sectional committee on this subject under the sponsorship of the Society has been organized by adding to the personnel of the Society's Committee D-4 on Road and Paving Materials representatives of several organizations that had not heretofore been officially represented in the activities of the committee. The membership of the committee as thus enlarged has been formally approved as the sectional committee and the committee met for organization during the group committee meetings in Washington on March 23. The personnel at that time comprised 81 members, representing 19 bodies, classified into 39 producers, 27 consumers and 15 general interests. The committee is now reviewing a number of A.S.T.M. methods for submission to A.E.S.C. for approval.

Sectional Committee on Wrought-Iron and Wrought-Steel Pipe and Tubing.—The sectional committee on this subject was organized in Pittsburgh on May 18 under the joint sponsorship of the American Society of Mechanical Engineers and the A.S.T.M. The scope of this committee's work has been defined as follows: "Standardization of the design, dimensions and material of welded wrought-iron pipe, of welded and seamless steel pipe, and of boiler tubing, including pipe and tubing for high temperatures and pressures." The several A.S.T.M. specifications covering iron and steel tubes and pipe, which are in charge of Committees A-1 on Steel and A-2 on Wrought Iron, will be reviewed by the sectional committee from the point of view of materials requirements. The Executive Committee has appointed the following members as A.S.T.M. representatives on the committee: H. H. Morgan, F. N. Speller, L. W. Spring and G. H. Woodroffe. The activities of this sectional committee will be suitably correlated with those of the Sectional Committee on Code for Pressure Piping.

The Sectional Committee on Specifications for Cast-Iron Pipe has continued its work during the year and has undertaken several extensive investigations having to do with physical tests and corrosion of pipe. A progress report is expected to be presented at this meeting. A final report has been prepared during the year by the Sectional Committee on Specifications for Special Trackwork Materials. The Society has been represented on this sectional committee by E. F. Kenney, with F. N. Speller as alternate. The report includes specifications for the materials entering into special track work and in these the specifications of the several interested national standardizing bodies have been used as a basis. Many A.S.T.M. specifications have been incorporated, either *in toto* by reference or by excerpting those portions which apply. The A.S.T.M. standards involved include those for rails, splice bars, track bolts, etc., and for iron and steel castings and for bar iron and steels.

The Sectional Committee on Pipe Flanges and Fittings, upon which the Society is represented but is not a sponsor, has brought out two standards having particular interest to the Society, namely, Tentative American Standard for Steel Pipe Flanges and Flanged Fittings and American Standard for Cast-Iron Pipe Flanges and Flanged Fittings. In the former the materials requirements have been taken from three A.S.T.M. specifications prepared for that purpose, namely, Tentative Specifications for Carbon-Steel Castings for Valves, Flanges and Fittings for High-Temperature Service (A 95 – 26 T), Standard Specifications for Alloy-Steel Bolting Material for High-Temperature Service (A 96 – 27) and Tentative Specifications for Forged or Rolled Steel Pipe Flanges for High-Temperature Service (A 105 – 27 T). In the latter, special requirements for gray-iron castings have been written pending the development by the Society of specifications suited for the purpose. Committee A-3 is at work now on this problem.

Acting upon an unanimous recommendation from the Sectional Committee on Numbering of Steels, the two sponsors for this project, namely, the Society of Automotive Engineers and the A.S.T.M., recommended that the project be discontinued in the belief that the preparation of a universal numbering system for steels is impracticable except by indexing existing specifications, and that further effort to establish such a system is inexpedient. As a result of this recommendation the American Engineering Standards Committee has discontinued this project.

Considerable progress has been made by the Sectional Committee on Scientific and Engineering Symbols and Abbreviations, on which the Society is represented by the Assistant Secretary. The Sub-Committee, of this Sectional Committee, on Mechanics, Structural Engineering and Testing Materials has prepared a compilation of some 50 suggested lists or lists now in use and, based upon this compilation, a recommended list will be prepared. The Society is also represented by the Assistant Secretary on the Sectional Committee on Standards for Graphics. The sectional committee has effected an organization and sub-committees are now functioning, the Society being represented on the Sub-Committee on Engineering and Scientific Graphs. The Society has also accepted an invitation to participate in the work of the Sectional Committee on Sheet Metal Gages.

Department of Commerce Activities:

In appropriate ways the Society has continued its contact and cooperation with the activities of the Division of Simplified Practice and the Commercial Standards Unit of the U. S. Bureau of Standards, Department of Commerce. While most of the simplified practice projects do not fall within the scope of work of the Society, there are a few that are of more or less direct interest. Recently there has been some activity respecting Simplified Practice Recommendations for Asphalt and Malleable Foundry Refractories. These subjects are of interest, respectively, to Committees D-4 on Road and Paving Materials and C-8 on Refractories and have been referred to these committees for consideration and recommendations.

Within the past six months the Bureau of Standards has organized a division for the purpose of promulgating recognized specifications as "Commercial Standards" upon specific request from some part of industry and in accordance with a procedure involving a survey of the field covered by the proposed standard and a conference of the industry, including producers, distributors and organized consumers. In its essentials it is understood that this procedure contemplates applying the principles worked out for simplified practice to the establishment of commercial standards of grade and quality. It is apparent that this newer activity of the Bureau will touch the Society's standards-making activities much more intimately than does the simplified practice work, and discussions with the officials of the Bureau are in progress to determine ways and means of correlation and cooperation between the Society and the Bureau in this work. There have so far been proposed three Commercial Standards in which the Society has been more or less directly interested and which have been under consideration in appropriate Society channels, namely, Commercial Standard No. 1, New Billet Steel Concrete Reinforcement Bars; Proposed Commercial Standard for Stoddard Solvent (a petroleum distillate for dry cleaning); and Proposed Commercial Standard for Chain Link Fence and Chain Link Fabric, Galvanized after Weaving (Copper-Bearing Steel).

Translation of A.S.T.M. Specifications:

Foreign language editions of certain selected A.S.T.M. specifications are published and distributed by the Bureau of Foreign and Domestic Commerce, Department of Commerce. The Society first gave permission for this work in 1916 when a Spanish and a French series were initiated by the Bureau. A Portuguese series was started in 1925 with the publication of two standards. During the last year 13 specifications have been added to the Portuguese series, making a total of 140 separate pamphlets published in the three foreign language groups, that is, 64 in Spanish, 61 in French and 15 in Portuguese.

The Bureau of Foreign and Domestic Commerce determines the usefulness of a standard for promotion of foreign trade from the data at hand and through consultation with exporters and manufacturers of the particular commodity with which the specification deals. The foreign service bureau arranges for translations and pays for the printing of 1000 copies which are distributed abroad to a large extent by its own officers and those of the Department of State. Exporters and manufacturers purchase a certain number of copies from the Superintendent of Documents for private distribution.

An endeavor has been made to correct the translations in the Spanish series in accordance with revisions, corrections or additions made by the Society. In revising and reprinting the Bureau of Foreign and Domestic Commerce has been guided by the requirements of manufacturing exporters and, therefore, not all of the issues released from 1916 to 1918 have been reprinted to agree with the latest adopted standards of the Society. Only one revision has been made in the French series since 1920.

In the Spanish language group, 24 are in good standing and in accordance with the standards of the Society. Ten numbers of the 40 remaining are now in course of revision. Manuscript for an additional number, Specifications for Zinc-Coated (Galvanized) Sheets (A 93 – 27), is now in print. There does not appear to be sufficient demand in foreign trade promotion for the revision of the 30 remaining numbers in this group, 10 of which have been discontinued or replaced by the Society. Twelve numbers in the French language group are in good standing and in accordance with the standards last adopted by the Society. There does not appear to be sufficient demand by the exporters in the industries concerned to warrant the expense on the part of the Bureau in printing corrections of the 49 remaining numbers. Fourteen of the numbers in the Portuguese series are in good standing and in accordance with the latest specifications adopted by the Society. The one issue which is now obsolete, Carbon Steel Rails (A 1 – 24), is under consideration for revision in accordance with the specifications adopted by the Society in 1927. A statement in the April number of the Bulletin lists the Portuguese, Spanish and French translations that are in good standing, a total at this time of 50.

In its program for the forthcoming fiscal year beginning July 1, 1928, the Bureau has under consideration six standard specifications of the Society. These are: Brass Forging Rod (B 15 – 18); Brass Rod, Free Cutting for Use in Screw Machines (B 16 – 18); Brass Ingot Metal for Sand Castings (B 30 – 22); Naval Brass Rods for

Structural Purposes (B 21 - 27); High Sheet Brass (B 36 - 27); and Solder Metal (B 32 - 21). These specifications may be added to the Spanish language group.

This cooperative work of the Society and the Bureau of Foreign and Domestic Commerce is of considerable importance in the promotion of American standard specifications in foreign trade and deserves the encouragement and support of the members of the Society who are in any way concerned with such trade. Both the Society and the Bureau will welcome comments, and particularly any recommendations regarding additions to any of the three language series.

Miscellaneous Cooperative Work:

The Society is represented upon a number of joint committees, as set forth in detail in the Year Book. Among those that have been active during the year are the following: The Joint Concrete Culvert Pipe Committee has completed the development of Specifications for Concrete Culvert Pipe and is presenting a report this year to the cooperating bodies. This report has been placed on the program of the annual meeting. The Society, through Committee A-1 on Steel, has been discussing with the American Marine Standards Committee the requirements for Specifications for Marine Boiler Steel Plates, seeking to bring about if possible the adoption of an identical specification by the two bodies. Good progress has been made during the year, the points of difference now having been reduced to one or two of relatively minor importance. Some further work has been done on definitions of terms relating to heat treatment by the joint committee handling that problem, which is being reported to the Society by Committee A-4. The activities of the several research committees in which the Society is interested are mentioned in the annual report of Committee E-9 on Correlation of Research and to some extent are covered by reports from those committees being presented at this annual meeting.

Some interesting work is being done by the Joint Committee on Boiler Feed Waters in the development of methods of sampling water, a problem that was suggested to the committee by the Society. The Society is also interested in the work of this committee on analysis of water. Cooperative work between the Bureau of Standards, American Wood Preservers Association and the A.S.T.M. through Committee D-7 on Timber, in the determination of density and thermal expansion constants of creosote oil has been practically completed and it is hoped to make a final report this year through Committee D-7. Committee D-2 on Petroleum Products and Lubricants joined with the appropriate committee of the American Leather Chemists Association in the study of the applicability of the Society's present methods for cloud and pour tests as applied to fatty oils, particularly neats foot oil, of particular interest to the leather industry. The Society through appointed representatives from Committee C-8 on Refractories is cooperating with other bodies in the activities of a Joint Committee on Foundry Refractories sponsored by the American Ceramic Society and the American Foundrymen's Association.

Continued cooperation with the Boiler Code Committee of the American Society of Mechanical Engineers has been an important activity throughout the year. This work has proved of considerable value, in that matters of materials requirements coming before the Boiler Code Committee come promptly to the Society's attention and are handled with a minimum of delay through appropriate channels. During the year several A.S.T.M. specifications have been added to the Boiler Code and others are at present under consideration.

On October 6, 1927, upwards of 250 members of the Society were guests of the Army Ordnance Association at its Ninth Annual Meeting held at Aberdeen Proving Ground, Aberdeen, Md. Throughout the day there was a continuous demonstration of Army weapons and equipment, having a particular appeal to American citizens interested in the military phases of national defense and having instructive value to executives and engineers of American industry.

Respectfully submitted on behalf of the Executive Committee,

H. F. MOORE,
President.

C. L. WARWICK,
Secretary-Treasurer.

REPORT OF COMMITTEE A-1
ON
STEEL

During the past year the committee has held two meetings, one on January 13 and the second on March 23, 1928. A third meeting will be held prior to the presentation of this report to the Society, at which the report will be reviewed and other matters considered.

The Advisory Committee has held three meetings at which matters concerning the general administrative affairs of the committee were considered.

The present membership of the committee is 165, of which 76 are classed as producers, 65 as consumers and 24 as general interests.

RECOMMENDATIONS AFFECTING STANDARDS AND TENTATIVE STANDARDS

The recommendations of the committee affecting standards and tentative standards are presented first in summarized form together with an analysis of the letter ballot on each item.

They are then referred to, where necessary, in greater detail, being grouped for convenience in the order of the respective subcommittees directly responsible for them.

I. PROPOSED REVISIONS IN STANDARDS

The committee recommends that the revisions in the following standards, which are given in full in Appendix I to this report, be submitted to letter ballot of the Society. These revisions are divided into two groups:

A—Revisions recommended for publication as tentative for one year before referring them to letter ballot of the Society for adoption as standard (items 1 to 5 and item 8 of Appendix I).

B—Revisions which the committee recommends be referred to letter ballot of the Society immediately by the necessary nine-tenths vote of the annual meeting, for adoption as standard (items 6 and 7 of Appendix I).

The standard specifications in each group are as follows:

GROUP A

Revisions Presented for Publication as Tentative:

For Structural Steel for Bridges (A 7 - 24);
For Structural Nickel Steel (A 8 - 24);
For Structural Steel for Buildings (A 9 - 24);
For Structural Silicon Steel (A 94 - 27);
For Billet Steel Concrete Reinforcement Bars (A 15 - 14);
Methods of Chemical Analysis of Plain Carbon Steel (A 33 - 24).

GROUP B

Revisions Presented for Immediate Adoption:

For Carbon-Steel and Alloy-Steel Forgings (A 18 - 27);
For Carbon-Steel Forgings for Locomotives (A 20 - 27).

II. PROPOSED REVISIONS IN TENTATIVE STANDARDS

The committee recommends that the revisions in the following tentative specifications, which are given in full in Appendix I to this report, be approved and that the specifications as thus revised be continued as tentative for another year:

For Structural Steel for Locomotives and Cars (A 113 - 27 T);
For Marine Boiler Steel Plates (A 114 - 27 T);
For Electric Cast-Steel Anchor Chain (A 77 - 20 T);
For Carbon-Steel Castings for Valves, Flanges and Fittings for High-Temperature Service (A 95 - 26 T);
For Lap-Welded and Seamless Steel Pipe for High-Temperature Service (A 106 - 27 T).

III. TENTATIVE SPECIFICATIONS ADVANCED TO STANDARD

The committee recommends that the following tentative specifications be advanced to standard without revision:

For Alloy Tool Steel (A 115 - 27 T);
For Forged or Rolled Steel Pipe Flanges for High-Temperature Service (A 105 - 27 T).

IV. PROPOSED NEW TENTATIVE STANDARDS

The committee recommends that the following proposed new tentative specifications be accepted for publication as tentative as appended to this report:[1]

For Iron and Steel Chain (a tentative revision of Standard Specifications A 56 - 24);
For Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless Steel Pipe for Ordinary Uses.

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[1] See pp. 697 and 729, respectively.—ED.

V. TENTATIVE STANDARDS

The committee recommends that the following tentative specifications be continued as tentative for another year without revision:

For Soft Steel Track Spikes (A 65 – 26 T);
For Steel Tie Plates (A 67 – 26 T);
For Cold-Rolled Strip Steel (A 109 – 27 T).

The above recommendations have been referred to letter ballot of the committee, which consists of 165 members; 131 ballots have been cast, 34 members having failed to return their ballots. The analysis of the vote of the committee is given in the following table:

Items	Affirmative	Negative	Not Voting[a]
I. PROPOSED REVISIONS IN STANDARDS			
1. Structural Steel for Bridges (A 7 – 24)	99	0	32
2. Structural Nickel Steel (A 8 – 24)	93	0	38
3. Structural Steel for Buildings (A 9 – 24)	97	0	34
4. Structural Silicon Steel (A 94 – 27)	94	0	37
5. Billet-Steel Concrete Reinforcement Bars (A 15 – 14)	82	3	46
6. Carbon-Steel and Alloy-Steel Forgings (A 18 – 27)	102	0	29
7. Carbon-Steel Forgings for Locomotives (A 20 – 27)	88	1	42
8. Methods of Chemical Analysis of Plain Carbon Steel (A 33 – 24)	98	1	32
II. PROPOSED REVISIONS IN TENTATIVE STANDARDS			
9. Structural Steel for Locomotives and Cars (A 113 – 27 T)	90	1	40
10. Marine Boiler Steel Plates (A 114 – 27 T)	82	0	49
11. Electric Cast-Steel Anchor Chain (A 77 – 20 T)	70	1	60
12. Carbon-Steel Castings for Valves, Flanges and Fittings for High-Temperature Service (A 95 – 26 T)	83	0	48
13. Lap-Welded and Seamless Steel Pipe for High-Temperature Service (A 106 – 27 T)	81	1	49
III. TENTATIVE SPECIFICATIONS ADVANCED TO STANDARD			
14. Forged or Rolled Steel Pipe Flanges for High-Temperature Service (A 105 – 27 T)	86	0	45
15. Alloy Tool Steel (A 115 – 27 T)	79	0	52
IV. PROPOSED NEW TENTATIVE STANDARDS			
16. Lap-Welded and Seamless Steel Pipe, Black and Galvanized, for Ordinary Uses	86	1	44
17. Iron and Steel Chain	73	2	56

[a] In this column are recorded the number of votes cast as "Not Voting" on the various items.

Total number of ballots cast	131
Number of members who failed to vote	34
Total Membership	165

The committee lost by death during the year two members who had long been associated with it, Mr. H. V. Wille, Consulting Vice-President of the Baldwin Locomotive Works and the Standard Steel Works Co., and Professor Gaetano Lanza. It formally passed resolutions in their memory.

HENRY V. WILLE
1869–1927

WHEREAS, Mr. Henry V. Wille, a member of this Committee and an honored associate, has passed from our presence into the Great Beyond;

RESOLVED, that we pause from the considerations of the day to record our sorrow and pay tribute to his memory. His position with the great commercial enterprise with which he was associated bears witness to his ability and sagacity.

It is the privilege of his associates at this time to recall his unfailing efforts on behalf of this Committee and the American Society for Testing Materials and their pleasure in having him as a fellow worker.

RESOLVED, that this memorial be made a part of the records of this Committee and that a copy thereof be sent to the Baldwin Locomotive Works and to his nearest of kin.

GAETANO LANZA

1848–1928

Committee A-1 on Steel of the American Society for Testing Materials, assembled in meeting at Washington, March 23, 1928, has learned with sincere regret of the death on March 21 of Gaetano Lanza, a member of the Society since 1899 and an Honorary Member since 1920.

Professor Lanza was a member of Committee A-1 for more than a quarter of a century and his interest in its work was always sincere and active, even under recent physical disability. The outstanding accomplishments of his life took place at the Massachusetts Institute of Technology where he taught for forty years. He was head of its Department of Mechanical Engineering for twenty-nine years and it was through his untiring efforts that this department reached the high standard it attained. He was one of the first to realize the importance of testing full-size specimens for columns and similar structures and he established the first laboratory for testing full-size structural timbers. He was one of the pioneers in aerodynamic research and in 1910 built a small wind-tunnel and carried on investigations of far-reaching importance. Following his retirement from teaching in 1911, he became consulting engineer to the Baldwin Locomotive Works.

THEREFORE BE IT RESOLVED, That Committee A-1 express its sorrow at the loss of this member, brilliant scholar, eminent teacher, gentle and loyal friend; and be it further

RESOLVED, That a copy of this Resolution be made a part of the records of this Committee and be made a part of its annual report to the Society.

The committee formally passed resolutions covering (*a*) the continuation of the joint committee formed in 1921 by Committee A-1 and Committee C-2 on Reinforced Concrete to investigate the physical properties of concrete reinforcement bars; (*b*) the standardization of concrete reinforcement bars; (*c*) cooperation with the American Railway Association on the revision of specifications for springs.

(*a*) WHEREAS, the Executive Committee under date of April 11, 1921, approved the following resolution:

"WHEREAS, reliable information in regard to the physical properties of plain, deformed and twisted bars of different grades of steel is undoubtedly required by engineers and manufacturers, therefore,

"BE IT RESOLVED, that this Sub-Committee recommend to Committee A-1 that the American Society for Testing Materials appoint a proper committee whose duty it shall be to thoroughly investigate the whole subject of physical properties in steel reinforcement bars, plain, deformed, or twisted, and rolled from the four different grades now in commercial use, in the form as rolled and in machined test specimens."

THEREFORE BE IT RESOLVED, that it is the sense of this meeting (January 13, 1928) that, in view of the largely changed conditions prevailing in the industry, the special Joint Committee should be continued with the request that it endeavor to formulate a program which in its judgment would be necessary in order to carry out the original instructions of the Executive Committee under the changed conditions; and that the Joint Committee report the result of its deliberations for the consideration of Committee A-1 on Steel and Committee C-2 on Reinforced Concrete.

(*b*) RESOLVED, that it is the sense of this meeting (January 13, 1928) that Committee A-1 should recommend that the Society endorse the effort of the Department of Commerce to simplify the grades of Concrete Reinforcement Bars.

RESOLVED, that it is the sense of this meeting (January 13, 1928) that Sub-Committee V is not prepared at this time to recommend the elimination of any of the grades in the Society's existing Standard Specifications for Billet-Steel Concrete Reinforcement Bars (Serial Designation: A 15 – 14).

(*c*) RESOLVED, that Committee A-1 request the Executive Committee to ask for the cooperation of the Mechanical Section of the American Railway Association in the revision of specifications for springs.

SUB-COMMITTEE ACTIVITIES

In the following the committee presents the foregoing recommendations in detail where necessary, as well as other features of its work, grouped for convenience in the order of the respective sub-committees responsible for them.

SUB-COMMITTEE II ON STRUCTURAL STEEL FOR BRIDGES, BUILDINGS AND ROLLING STOCK

This sub-committee is submitting revisions in several specifications for Structural Steel to harmonize them with those of the American Railway Engineering Association. Requirements for copper steel have also been included in several specifications. At the instigation of the sub-committee, a letter has been addressed by the Secretary to a number of national engineering societies and associations with a view to obtaining their views on the desirability of increasing the ultimate tensile strength in specifications for structural steel from a range of 55,000 to 65,000 to a range of 60,000 to 70,000 lb. per sq. in., with corresponding changes in other properties.

SUB-COMMITTEE IV ON SPRING STEEL AND STEEL SPRINGS

Sub-Committee IV has been strengthened by the addition of a number of spring manufacturers and railway spring consumers. The augmented committee is seeking cooperation with the A. R. A. Specifications Sub-Committee on Springs and the Railroad Spring Manufacturers Technical Committee and expects to present in the near future, revisions in our specifications for railway springs.

SUB-COMMITTEE V ON STEEL REINFORCEMENT BARS

This sub-committee has made several revisions in the Standard Specifications for Billet-Steel Concrete Reinforcement Bars, in keeping with demands of the trade. At the instance of Sub-Committee V, Committee A-1 passed resolutions, given elsewhere in this report, regarding the standardization of grades of concrete reinforcement, bars, which is being sponsored by the U. S. Department of Commerce and also regarding the continuation of the joint committee formed by Committees A-1 and C-2 in 1921 to investigate the physical properties of concrete reinforcement bars.

SUB-COMMITTEE VI ON STEEL FORGINGS AND BILLETS

This sub-committee has adopted a definition for "seams" in steel forgings and a definition for "injurious seams and other defects" in steel forgings. These definitions are given in full in Appendix II to this report.

The sub-committee has been actively engaged for several years investigating the influence of reduction from bloom to forging. An interesting and valuable report is expected in the near future.

SUB-COMMITTEE IX ON STEEL TUBING AND PIPE

This sub-committee is presenting new specifications for publication as tentative, covering steel pipe for ordinary purposes.[1] A demand for such a specification has been formally entered by the Committee on Code for Pressure Piping functioning under the rules of procedure of the American Engineering Standards Committee.

SUB-COMMITTEE XVI ON CAST-STEEL CHAIN

The sub-committee is presenting completely revised Specifications for Electric Cast-Steel Anchor Chain[2] in line with current practices and requirements of the trade.

SUB-COMMITTEE XXI ON STEEL FOR WELDING

The membership of the sub-committee has been increased by the addition of several representatives of the American Welding Society. The sub-committee will concern itself in the preparation of specifications for steel for fusion welding.

SUB-COMMITTEE XXII ON VALVES, FLANGES AND FITTINGS FOR HIGH-TEMPERATURE SERVICE

The sub-committee has considered the preparation of specifications for materials for use at temperatures of 1000 and 1200° F. However, questionnaires sent to the oil industry and the central station group disclosed the fact that the practice in equipment for use at these temperatures is not sufficiently standardized and that while some manufacturers do make equipment for service at temperatures as high as 1000° F., it was felt that there is insufficient knowledge upon which to base reasonably conservative specifications. The project is in abeyance until there is an established basis for the requirements.

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[1] See p. 729.—ED. [2] See p. 702.—ED.

The sub-committee is recommending the advancement to standard of the Specification for Forged and Rolled Steel Flanges (A 105 – 27 T) and revisions in the Tentative Specifications for Lap-Welded and Seamless Steel Pipe for High-Temperature Service (A 106 – 27 T) and for Carbon-Steel Castings for Valves, Flanges and Fittings for High-Temperature Service (A 95 – 26 T) which are to be continued as tentative as revised for another year.

The committee has elected the following officers to serve for the ensuing two years: J. B. Young, chairman; E. F. Kenney, vice-chairman; H. H. Morgan, vice-chairman; and V. H. Lawrence, secretary.

This report has been submitted to letter ballot of the committee, which consists of 165 members; 110 members returned their ballots, of whom 108 have voted affirmatively, none negatively and 2 have marked their ballots "not voting."

Respectfully submitted on behalf of the committee,

G. H. WOODROFFE,
Secretary.

J. B. YOUNG,
Chairman.

EDITORIAL NOTE

The proposed revisions of the Standard Specifications for Structural Steel for Bridges; for Structural Nickel Steel; for Structural Steel for Buildings; for Structural Silicon Steel; for Billet-Steel Concrete Reinforcement Bars; and Methods of Chemical Analysis of Plain Carbon Steel were accepted for publication as tentative and appear on pages 1113, 1114 and 1117.

The proposed revisions of the Standard Specifications for Carbon-Steel and Alloy-Steel Forgings, and for Carbon-Steel Forgings for Locomotives were approved at the annual meeting by a nine-tenths vote and were subsequently adopted by letter ballot of the Society on September 1, 1928. The standard specifications as thus revised appear in the 1928 Supplement to Book of A.S.T.M. Standards.

The proposed revisions of the Tentative Specifications for Structural Steel for Locomotives and Cars; for Marine Boiler Steel Plates; for Electric Cast-

Steel Anchor Chain; for Carbon-Steel Castings for Valves, Flanges and Fittings for High-Temperature Service; and for Lap-Welded and Seamless Steel Pipe for High-Temperature Service were accepted. The tentative specifications in their revised form appear on pages 712, 719, 702, 724 and 733, respectively.

The Tentative Specifications for Alloy Tool Steel, and for Forged or Rolled Steel Pipe Flanges for High-Temperature Service were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on September 1, 1928, and appear in the 1928 Supplement to Book of A.S.T.M. Standards.

The proposed Specifications for Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless Steel Pipe for Ordinary Uses were accepted for publication as tentative as were also the proposed Specifications for Iron and Steel Chain to supersede, when adopted, the present standard specifications. The tentative specifications appear on pages 729 and 697, respectively.

APPENDIX I

PROPOSED REVISIONS IN STANDARDS AND TENTATIVE STANDARDS FOR STEEL

In this appendix are given proposed revisions in certain standard and tentative specifications, which, for convenience, are numbered from 1 to 12, inclusive. In connection with each title is given the reference to the publication in which the specifications appear in their present form.

PROPOSED REVISIONS IN STANDARDS

No. 1.—Standard Specifications for Structural Steel for Bridges: A 7 - 24.[1]

Section 3.—Add a new Paragraph (*b*) to read as follows:

(*b*) When copper steel is specified, the following requirement as to copper shall govern:

Copper.......................... not less than 0.20 per cent

Section 4.—Change to read as follows by the addition of the italicized words:

An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur *and also copper, when copper steel is specified.* This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative and *the percentages of phosphorus and sulfur and also copper, when copper steel is specified,* shall conform to the requirements specified in Section 3 (*a*) *and* (*b*).

Table II.—Add a note to Table II on Permissible Overweights of Rectangular Plates Ordered to Thickness, to read as follows:

Note.—The weight of individual plates ordered to thickness shall not exceed the nominal weight by more than one and one-third the amount given in this table.

No. 2.—Standard Specifications for Structural Nickel Steel: A 8 - 24.[2]

Table II.—Add a note to Table II on Permissible Overweights of Rectangular Plates Ordered to Thickness, to read as follows:

Note.—The weight of individual plates ordered to thickness shall not exceed the nominal weight by more than one and one-third the amount given in this table.

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[1] 1927 Book of A.S.T.M. Standards, Part I, p. 63.

[2] *Ibid.*, p. 70.

NO. 3.—STANDARD SPECIFICATIONS FOR STRUCTURAL STEEL FOR BUILDINGS: A 9 – 24.[1]

Section 2.—Add a new Paragraph (*b*) to read as follows:

(*b*) When copper steel is specified, the following requirement as to copper shall govern:

Copper............................ not less than 0.20 per cent

Section 3.—Change to read as follows by the addition of the italicized words:

3. (*a*) A carbon determination *and also copper, when copper steel is specified,* shall be made of each melt of bessemer steel, and determinations for manganese, phosphorus and sulfur representing the average of the melts applied for each 12-hour period.

(*b*) An analysis of each melt of open-hearth steel shall be made for carbon, manganese, phosphorus and sulfur *and also copper, when copper steel is specified.*

(*c*) These analyses shall be made by the manufacturer from test ingots taken during the pouring of each melt. The chemical composition thus determined shall be reported to the purchaser or his representative and *the percentages of phosphorus and sulfur, and also copper, when copper steel is specified* shall conform to the requirements specified in Section 2 (*a*) *and* (*b*).

Table II.—Add a note to Table II on Permissible Overweights of Rectangular Plates Ordered to Thickness, to read as follows:

NOTE.—The weight of individual plates ordered to thickness shall not exceed the nominal weight by more than one and one-third the amount given in this table.

NO. 4.—STANDARD SPECIFICATIONS FOR STRUCTURAL SILICON STEEL: A 94 – 27.[2]

Table II.—Add a note to Table II on Permissible Overweights of Rectangular Plates Ordered to Thickness, to read as follows:

NOTE.—The weight of individual plates ordered to thickness shall not exceed the nominal weight by more than one and one-third the amount given in this table.

NO. 5.—STANDARD SPECIFICATIONS FOR BILLET-STEEL CONCRETE REINFORCEMENT BARS: A 15 – 14.[3]

Section 2.—Omit Paragraph (*a*) reading as follows, designating Paragraph (*b*), Section 2:

The structural-steel grade shall be used unless otherwise specified.

Section 5.—Change to read as follows by the addition of the italicized words and figures:

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[1] 1927 Book of A.S.T.M. Standards, Part I, p. 81.

[2] *Ibid.*, p. 76.

[3] *Ibid.*, p. 132.

The steel shall conform to the following requirements as to chemical composition:

Phosphorus	Bessemer	not over 0.10 per cent
	Open-hearth *Basic*	" " 0.05 "
	Open-hearth Acid	" " *0.08* "

Section 8.—Change the requirement for tensile strength of intermediate grade of both plain and deformed reinforcement bars as given in the table of Paragraph (*a*) from "70,000 to 85,000" to read "70,000 to 90,000," and add to the requirement for elongation in 8 in. of intermediate grade plain bars the provision "but not less than 16 per cent" and to the requirement for intermediate grade deformed bars "but not less than 14 per cent," both of these provisions to be subject to the modifications of Section 9.

No. 6.—Standard Specifications for Carbon-Steel and Alloy-Steel Forgings: A 18 - 27.[1]

Section 13.—Change to read as follows by the addition of the italicized words, making the present Section 13, Section 13 (*a*):

> 13. (*a*) *When annealed or quenched-and-tempered forgings are specified*, if the results of the physical tests of any test lot of forgings do not conform to the requirements specified, the manufacturer may re-treat such lot one or more times and retests shall be made as specified in Section 12.

Add a new Paragraph (*b*) to read as follows:

> (*b*) When untreated forgings (Classes A, B, D) are specified, if the results of the physical tests of any test lot of forgings do not conform to the requirements specified, the manufacturer may anneal such lot one or more times and retests shall be made as specified in Section 12.

No. 7.—Standard Specifications for Carbon-Steel Forgings for Locomotives: A 20 - 27.[2]

Section 13.—Change Paragraph (*a*) to read as follows by the addition of the italicized words:

> (*a*) *When annealed forgings are specified*, if the results of the physical tests of any test lot do not conform to the requirements specified, the manufacturer may re-anneal such lot but not more than three additional times unless authorized by the purchaser, and retests shall be made as specified in Section 12.

Add a new Paragraph (*b*) to read as follows:

> (*b*) When untreated forgings are specified, if the results of the physical tests of any test lot of forgings do not conform to the requirements specified, the manufacturer may anneal such lot, but not more than three times, unless authorized by the purchaser, and retests shall be made as specified in Section 12.

Reletter the present Paragraph (*b*) to read Paragraph (*c*) and change to read as follows by the addition of the italicized words and the omission of those in brackets:

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[1] 1927 Book of A.S.T.M. Standards, Part I, p. 179.

[2] *Ibid.*, p. 200.

(*c*) [When annealed forgings are specified,] *In the case of annealed forgings,* if the fracture of any test specimen shows over 15 per cent crystallin, a second test shall be made. If the fracture of the second specimen shows over 15 per cent crystallin, the forgings represented by such specimen shall be re-annealed. The fracture shall be considered crystallin if the crystals which it contains are so large that the cleavage planes or sides of these crystals are easily visible to the eye.

NO. 8.—STANDARD METHODS OF CHEMICAL ANALYSIS OF PLAIN CARBON STEEL: A 33 - 24.[1]

New methods of sampling rolled and forged steel products for check analysis are recommended for insertion at the head of the Standard Methods as appended hereto.[2]

PROPOSED REVISIONS IN TENTATIVE STANDARDS

NO. 9.—TENTATIVE SPECIFICATIONS FOR STRUCTURAL STEEL FOR LOCOMOTIVES AND CARS: A 113 - 27 T.[3]

Table II.—Add a note to Table II on Permissible Overweights of Rectangular Plates Ordered to Thickness, to read as follows:

> NOTE.—The weight of individual plates ordered to thickness shall not exceed the nominal weight by more than one and one-third the amount given in this table.

NO. 10.—TENTATIVE SPECIFICATIONS FOR MARINE BOILER STEEL PLATES: A 114 - 27 T.[4]

Section 4.—Change the last sentence to read as follows by the addition of the italicized words:

> The chemical composition thus determined shall be reported to the purchaser or his representative and *the percentages of phosphorus and sulfur* shall conform to the requirements specified in Section 3.

NO. 11.—TENTATIVE SPECIFICATIONS FOR ELECTRIC CAST-STEEL ANCHOR CHAIN: A 77 - 20 T.[5]

These specifications have been completely revised and are appended hereto[6] in their proposed revised form.

NO. 12.—TENTATIVE SPECIFICATIONS FOR CARBON-STEEL CASTINGS FOR VALVES, FLANGES AND FITTINGS FOR HIGH-TEMPERATURE SERVICE: A 95 - 26 T.[7]

Add a new Section 9, to read as follows, renumbering the subsequent sections accordingly:

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[1] 1927 Book of A.S.T.M. Standards, Part I, p. 276.

[2] See p. 756.—ED.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 651 (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 31.

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 658 (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 38.

[5] *Proceedings*, Am. Soc. Testing Mats., Vol. XX, Part I, p. 508 (1920); also 1927 Book A.S.T.M. Tentative Standards, p. 27.

[6] See p. 702.—ED.

[7] *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, p. 637 (1926); also 1927 Book A.S.T.M. Tentative Standards, p. 43.

9. *Hydrostatic Tests.*—Each casting shall be tested after machining to the hydrostatic pressures specified in the table below (Note 1), and shall show no leaks. Castings ordered under these specifications for working pressures other than those listed below, shall be tested to such pressures as may be agreed upon:

CLASS OF CASTINGS, WORKING STEAM PRESSURE, LB. PER SQ. IN.	STANDARD TEST PRESSURE, LB. PER SQ. IN.
250	750
400	1000
600	1500
900	2000
1350	3000

Section 13.—Change Paragraph (*a*) to read as follows by the addition of the italicized words:

(*a*) The castings shall be *clean and* free from injurious defects.

Add a new Paragraph (*b*) to read as follows:

(*b*) The castings shall not be peened to stop leaks.

Reletter the present Paragraph (*b*) to read Paragraph (*c*) and change the last sentence to read as follows by the addition of the italicized words:

All castings shall be heat-treated after welding in accordance with the requirements in Section 3, *except that with permission of the inspector, castings with minor welds need not be re-heat-treated.*

Section 15.—Change Paragraph (*a*) to read as follows by the addition of the italicized figure and the omission of that in brackets:

Unless otherwise specified, any rejection based on tests made in accordance with Section 6 shall be reported within [5] *12* working days from the receipt of samples.

Explanatory Note.—Add a sentence at the end of this note, to read as follows:

The hydrostatic test pressures shown in Section 9 were taken from the above standards.

No. 13.—TENTATIVE SPECIFICATIONS FOR LAP-WELDED AND SEAMLESS STEEL PIPE FOR HIGH-TEMPERATURE SERVICE: A 106 – 27 T.[1]

Section 2.—Omit Paragraph (*b*) of this section, reading as follows:

All welded pipe shall be given a double welding operation.

Reletter Paragraph (*c*) to read Paragraph (*b*) and change to read as follows by the addition of the italicized words:

(*b*) Welded pipe 2 in. or over in nominal diameter shall be made by the lap-weld process. All pipe 1½ in. or under in nominal diameter shall be made by the seamless process, ***and may be either hot finished or cold drawn and annealed.***

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 667 (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 52.

Reletter Paragraph (*d*) to read Paragraph (*c*) and change to read as follows by the addition of the italicized words:

(*c*) Unless otherwise specified, seamless pipe *2 in. or over in nominal diameter* shall be furnished hot finished. Upon agreement, cold drawn and annealed pipe may be furnished.

Section 4 (*a*).—In the headings of the last two columns in the table of physical properties, change "Low Carbon" to read "Grade A (Note 2)" and "Medium Carbon" to read "Grade B," respectively.

Section 6.—Change Paragraph (*a*) from its present form: namely,

(*a*) For welded pipe, a section of pipe 6 in. long shall be flattened between parallel plates until the distance between the plates is one-third the outside diameter of the pipe, with the weld located 90 deg. from the line of direction of the applied force, without developing cracks.

to read as follows:

(*a*) For welded pipe, a section of pipe 6 in. long shall be flattened between parallel plates with the weld located at 90 deg. from the line of direction of the applied force, until opposite walls of the pipe meet. No opening in the weld shall take place until the distance between the plates is two-thirds of the original outside diameter of the pipe. No cracks or breaks in the metal elsewhere than in the lap-weld shall occur until the distance between the plates is one-third of the original outside diameter of the pipe. Evidence of laminations or burnt material shall not develop during the entire flattening process. When double-welded pipe is furnished on special order, the flattening test shall show no opening at the weld until the distance between the plates is one-third of the original outside diameter of the pipe.

In the first line of the first sentence of Paragraph (*b*), change "low carbon" to read "Grade A."

In the first line of the first sentence of Paragraph (*c*), change "medium carbon" to read "Grade B."

Table I.—Delete Table I on Dimensions and Weights of Pipe for 250, 400, 600, 900 and 1350-lb.-per-sq.-in. Standards for High Temperatures and all mention of it from the specifications, pending consideration and revision of the table by the new A.E.S.C. Sectional Committee on the Standardization of Wrought-Iron and Wrought-Steel Pipe and Tubing. After the table has been passed upon by that committee, it will be considered for reinsertion in these specifications. In the meantime the equivalent of Table I should be retained as Appendix A in the A.E.S.C. Steel Flange Standard.

Section 11 (*a*).—Change to read as follows by the addition of the italicized words and the omission of those in brackets:

The [standard weights and] nominal thicknesses for pipe of various diameters [are given in Table I] *shall be specified in the order.*

Section 12.—Change to read as follows by the addition of the italicized words and the omission of those in brackets:

12. The weight of the pipe shall not exceed that [specified in Table I *corresponding to the nominal thickness* by more than 5 per cent for the 250 400, 600 and 900-lb.-per-sq.-in. standards, nor more than 10 per cent fo the 1350-lb. standard.

Section 17.—Change to read as follows by the omission of the words in brackets:

Each length of pipe shall be marked with appropriate symbols to show by whom manufactured [, the classification as regards working steam pressure] and that it conforms to these specifications.

Explanatory Notes.—Change Note 1 to read as follows by the addition of the italicized words and the omission of those in brackets:

NOTE 1.—This contemplates temperatures from 450 to 750° F. (232 to 400° C.) or at the discretion of the designing engineer, higher temperatures with appropriate pressures may be used. Reference may be made to the dimensional *pipe* standards *for these pressures and temperatures given in Appendix A to the Tentative American Standard (B 16 - 1927) for Steel Pipe Flanges and Flanged Fittings.* [reproduced in Table I for various pressures at this high temperature formulated at the suggestion of Sub-Committee No. 3 on Steel Flanges and Flanged Fittings of the Sectional Committee on Pipe Flanges and Fittings. This table is to be published as an appendix to the report of Sub-Committee No. 3 and, under the procedure of the American Engineering Standards Committee, will in due course be presented for approval as a Tentative American Standard by the American Society of Mechanical Engineers.]

Change Note 2 to read as follows by the addition of the italicized words and the omission of those in brackets:

NOTE 2.—[Low-carbon seamless tubing] *Grade A* rather than [medium-carbon] *Grade B seamless tubing* should be used for cold bending or *for* fusion *or forge* welding. The purpose for which pipe is to be used should be stated on the face of the order.

APPENDIX II

PROPOSED DEFINITIONS OF SEAMS AND INJURIOUS SEAMS AND DEFECTS IN FORGINGS

The following definitions have been adopted by Committee A-1 for the information of Sub-Committee VI on Steel Forgings and Billets and for the information of Committee A-1:

Seams in Steel Forgings.—A separation of the metal as determined by splitting of a chip taken at right angles to or parallel with the direction of the seam.

Injurious Seams and Defects in Steel Forgings.—Seams or other surface imperfections in finished forgings will not be considered injurious if they can be removed by machining the surface of the forging to a depth of $\frac{1}{64}$ in. for each inch in dimension of the forging.

NOTE.—The depth of the imperfections may be developed by taking several light cuts with a chipping tool until the deepest chip does not break at the line of the imperfection, or by filing or machining at right angles to the line of the imperfection until its depth has been established.

PROGRESS REPORT OF THE JOINT COMMITTEE ON INVESTIGATION OF THE EFFECT OF PHOSPHORUS AND SULFUR IN STEEL

The Joint Committee on Investigation of the Effect of Phosphorus and Sulfur in Steel was formed in 1919 under the joint initiative of the American Society for Testing Materials, the U. S. Bureau of Standards and the then existing U. S. Railroad Administration. Its personnel has consisted of representatives from the following organizations:

U. S. Bureau of Standards;
American Society for Testing Materials;
American Railway Association, Mechanical Division;
U. S. War Department;
U. S. Navy Department;
Society of Automotive Engineers;
Society of Naval Architects and Marine Engineers;
National Research Council;
Association of American Steel Manufacturers;
Steel Founders' Society of America;
American Foundrymen's Association.

During the year representatives have been added from the American Petroleum Institute in the persons of Messrs. E. P. Bly and A. D. Sanderson. Mr. F. N. Speller has been added as a third representative of the Association of American Steel Manufacturers.

Previous reports of the Joint Committee have outlined the plan of investigation. Briefly, the plan includes a study of the effect of phosphorus and sulfur in steel under four headings:

Series A, in which the variable, sulfur, is "residual," that is, sulfur is present in the steel through its presence in materials charged in the furnace.
Series B, in which the variable, sulfur, is "added" during the later stages of manufacture;
Series C, in which the variable, phosphorus, is "residual."
Series D, in which the variable, phosphorus, is "added."

The steels in each series are considered under six classifications or groups as follows:

GROUP	MATERIAL	APPROXIMATE CARBON RANGE, PER CENT	APPROXIMATE MANGANESE RANGE, PER CENT
I.	Rivet Steel, Tubes, etc.	0.06 – 0.12	0.35 – 0.40
II.	Plates and Structural Shapes	0.16 – 0.22	0.35 – 0.40
III.	Forgings	0.45 – 0.55	0.50 – 0.60
IV.	Wheel, Tire and Rail Steel	0.65 – 0.75	0.60 – 0.70
V.	Spring Steels	0.95 – 1.05	0.35 – 0.45
VI.	Castings	....	....

These groups cover practically all of the usual carbon ranges of materials covered in A.S.T.M. specifications.

In addition to recording progress of the committee's work during the year, this report gives also a résumé of what the committee has so far accomplished. The several references should be consulted for details of work completed and previously reported.

STUDIES OF EFFECT OF RESIDUAL SULFUR (SERIES A)

Rivet Steel (Group I):

The committee's studies of the effect of sulfur on rivet steel have been fully reported[1] and formal conclusions were drawn and presented in 1926.[2] In substance the committee concluded that sulfur present in commercial rivet steel of the type studied up to at least 0.06 per cent is not detrimental, the tests having shown no systematic relation between any of the physical properties determined and sulfur content up to 0.06 per cent.

Structural Steel Plates (Group II):

The studies of the committee to determine the effect of sulfur on structural steel plates have also been completed and tests reported in 1924.[3] Last year the committee presented formal conclusions on this series of tests[4] which in substance were that sulfur present in commercial plate material up to at least 0.077 per cent, which was the highest sulfur content examined, is not detrimental, the tests showing no systematic relation between any of the physical properties determined and the sulfur up to 0.077 per cent.

Forging Steel (Group III):

Eight heats of basic open-hearth steel have been manufactured under the direction of the committee to determine the effect of sulfur on forging steels, comprising Group III of the program. In this group the desired chemical composition was carbon, 0.45 to 0.55 per cent; manganese, 0.50 to 0.60 per cent; and phosphorus under 0.02 per cent. The steel was successfully manufactured to meet these requirements by the Jones & Laughlin Steel Co. in accordance with arrangements made through the Association of American Steel Manufacturers. The sulfur contents of the eight heats determined by analysis of billets are: 0.031, 0.038, 0.052, 0.061, 0.069, 0.070, 0.097 and 0.116 per cent. The material has been supplied in the form of 1-in. rolled rounds, 2-in. hammer-forged rounds and 8-in. pressed-forged rounds. One-half of the material has been annealed and one-half quenched and tempered and the material distributed to the laboratories for test. At the present time some preliminary tests and macrographs of etched sections of the 2-in. and 8-in. forged rounds are being made, and a start has been made in carrying out the physical tests.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 94 (1922); also Vol. 24, Part I, pp. 96 and 108 (1924).

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, p. 114 (1926).

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 24, Part I, p. 185 (1924).

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 135 (1927).

The following information on melting and rolling practice and on heat treatment of the 1-in., 2-in. and 8-in. rounds is given:

All heats were made in stationary types of basic open-hearth furnaces. The sulfur was introduced by the use of high-sulfur scrap or in the pig iron. Ladle additions of coal were made in several cases to raise the carbon content to the desired percentage. Records of the charges and times for making heats were kept. Each heat was tapped into a 50-ton ladle which was filled to overflowing. The teeming was done in Gathmann molds, using six to seven molds 18 by 18 in. in size, and three 24 by 26 in. in size. The usual procedure was to fill one or two of the regular type molds used by the company in casting ingots and then to cast the ingots for the committee in the prescribed Gathmann molds. The average time consumed for filling the 18 by 18-in. molds was about one minute, and for the larger type molds about 1½ minutes.

The rolling of the heats containing higher sulfur, namely, Nos. 6371, 6376 and 3106, was observed. The 18 by 18-in. ingots were given nine passes in the first series of rolls and seven passes in the second series, the final cross-section of the billets being 4 by 4 in. The ingots of heat No. 6371 containing 0.070 per cent of sulfur rolled rather well, showing few if any cracks in the finished billets. In rolling heat No. 3106, which contained 0.116 per cent of sulfur, the "hot tops" of two of the ingots broke off. A number of cracks and checks were noted in the finished billets. The rolling of the 22-in. ingots of heat No. 6376, containing 0.097 per cent of sulfur, was carried out on a larger mill than the preceding heats above described. The first of these ingots was given thirty passes while the remaining two were given twenty-six passes. The finished billets, which had a cross-section of 9 by 9 in., showed several cracks. The "hot tops" in particular showed bad longitudinal cracks.

The 4 by 4-in. billets were rolled into 1-in. rounds and hammer-forged into 2-in. rounds at the Jones & Laughlin plant, while the 9 by 9-in. billets were forged into 8-in. rounds at the Carnegie Steel Co.

The chemical compositions of the eight heats, determined from samples taken from billets, except as noted, is as follows:

Heat	Carbon, per cent	Manganese, per cent	Phosphorus, per cent	Sulfur, per cent	Silicon, per cent
No. 3112	0.59	0.75	0.015	0.031	....
No. 3117	0.51[a]	0.55[a]	0.012[a]	0.038	0.21[a]
No. 5942	0.58	0.67	0.013	0.052	0.025[a]
No. 3109	0.48	0.63	0.012	0.061	0.24[a]
No. 6373	0.56	0.63	0.010	0.069	0.29[a]
No. 6371	0.49	0.72	0.018	0.070	0.25[a]
No. 6376	0.46	0.68	0.017	0.097	0.23[a]
No. 3106	0.54	0.47	0.012	0.116	0.31[a]

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[a] Analysis from ladle sample.

In all, there are 208 1-in. rounds, 208 2-in. rounds and 160 8-in. rounds. These were heat-treated according to the following schedule at the Navy Yard, Washington, D. C., under the supervision of the Bureau of Standards acting for the committee.

Annealing Operation.—All specimens were heated from room temperature (with furnace) to 1500° F. and held at this temperature as follows:

Size	Time of "Soaking"
1-in. rounds	1 hour
2-in. rounds	1½ hours
8-in. rounds	4 hours

The steels were cooled in the furnace subsequent to the "soaking" period.

Quenching and Tempering Operation.—After annealing, one-half of the specimens of each size of each heat was set aside and the other half was treated as follows:

Size	Heated to, deg. Fahr.	Time at 1500° F., hours	Time of Quench in Water, minutes	Drawing Temperature, deg. Fahr.	Time at Drawing Temperature,[a] hours
1-in. rounds	1500	1	½	1175	1
2-in. rounds	1500	1½	1¼	1175	1½
8-in. rounds	1500	4	6	1125	4

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[a] Specimens were cooled in the furnace after holding at temperature for the required time.

The quenched-and-tempered bars were checked for hardness. Specifications required that no bar of the same size and heat should vary more than 15 from the average Brinell hardness of all the specimens of the particular size and heat. All specimens came within the range specified save in one or two instances in which the variation was so small as to be within the range of error in reading. These results were therefore accepted as showing uniform heat treatment.

Wheel, Tire and Rail Steels (Group IV):

The procurement of material for the tests to determine the effect of sulfur on steels of Group IV is now under discussion with the Association of American Steel Manufacturers.

Spring Steels (Group V):

As announced in its report a year ago[1] the Joint Committee has decided to omit Group V of the original program.

Castings (Group VI):

Similarly, it has been decided, after consultation with the steel foundrymen, not to proceed with the determination of effect of sulfur on steel castings (Group VI) for reasons explained in the committee's report last year.[1]

STUDIES OF EFFECT OF ADDED SULFUR (SERIES B)

The study of the effect of added sulfur has been considered not so important as the studies of effect of residual sulfur and only one series of tests has been made, although that series was quite a comprehensive one. It comprised tests of structural, forging and rail steels falling within Groups II, III and IV, and the results were reported in 1923.[2]

STUDIES OF EFFECT OF RESIDUAL PHOSPHORUS (SERIES C)

The determination of the effect of residual phosphorus in the wrought steels that comprise Groups I to V inclusive has been deferred since, after discussion with steel makers and users, it has appeared that other parts of the phosphorus program are more important and should be given precedence.

Cast Steels (Group VI):

Thus, conferences with representatives of the steel founders established the importance of proceeding with the tests to determine the effect of phosphorus in cast steels. In the report a year ago[1] there was outlined a tentative program that had been prepared by the committee. The manufacture of cast-steel test bars in accordance with this program has now been completed, the steel having been manufactured by the Atlantic Steel Castings Co. under the direction of the committee, the cost of manufacture having been met by funds raised by steel casting companies through the American Foundrymen's Association and the Steel Founders' Society of America. Two classes of acid open-hearth steel were manufactured, designated Class A with desired carbon 0.25 per cent, and Class B with desired carbon 0.45 per cent. In each heat the desired manganese was 0.70 per cent, desired sulfur 0.045 per cent, desired silicon 0.35 per cent. The two heats are representative of normal acid open-hearth casting steel. In Class A five heats were desired with phosphorus ranging from 0.025 to 0.10 per cent; in Class B three heats were desired with phosphorus ranging from 0.025 to 0.07 per cent.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 131 (1927).

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 105 (1923).

The chemical compositions of these eight heats as finally produced and accepted by the committee are given below:

	HEAT	CARBON, PER CENT	MANGANESE, PER CENT	SULFUR, PER CENT	SILICON, PER CENT	PHOSPHORUS, PER CENT
Class A........	No. 1275	0.28	0.78	0.043	0.39	0.034
	No. 1279	0.30	0.73	0.042	0.33	0.042
	No. 1282	0.29	0.83	0.047	0.32	0.063
	No. 1284	0.28	0.60	0.045	0.33	0.070
	No 1281	0.26	0.75	0.044	0.36	0.093
Class B........	No. 1277	0.48	0.78	0.051	0.39	0.037
	No. 1276	0.48	0.70	0.042	....	0.050
	No. 1280	0.47	0.72	0.044	0.37	0.065

The following data respecting melting and casting practice and preparation of test bars are given:

All heats were made in a stationary-type acid open-hearth furnace of 10-ton capacity. The desired sulfur content was obtained by the addition of iron pyrites while the phosphorus was introduced by adding ferro-phosphorus. All additions were made in the furnace, excepting manganese, which was added in small lumps in the ladle. Each heat was tapped into a 10-ton ladle, the average heat producing about 7½ tons of steel. The castings for the test bars were made in open types of molds, each mold producing six test bars. The same sand mixture for making molds was used throughout, this consisting of a sharp silica sand mixed with the proper amount of fire clay. Each mold was jar-rammed 100 times and after that thoroughly dried in the oven. Before pouring the molds were placed upon racks and carefully leveled with a spirit-level in order that they might be evenly filled in pouring. The finished casting consisted of a solid block on the bottom of which were six test bars each $1\frac{1}{8}$ in. square by 12 in. long. In each of the heats containing 0.05 per cent of phosphorus or less, several castings in line of the regular production of the Atlantic Steel Castings Co. were made, following which the test bars were cast; while for the heats containing over 0.05 per cent phosphorus, the steel prior to being poured into molds for test bars was poured into carefully selected castings, mostly for the Atlantic Steel Castings Co.'s own use where chemical composition was not considered important. The balance of the steel in the ladle, after filling ten molds for test bars, was used in the same manner as indicated above before making the test bars.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 131 (1927).

All castings when removed from molds were sand blasted. The test bars were subsequently cut, by means of an acetylene torch, from the blocks with which they were cast. All bars were then inspected and the 45 best bars of each group selected.

The bars in each group were divided into three lots. The bars of the first lot were annealed, of the second lot normalized, and of the third lot normalized and drawn.

The following procedure was observed in these heat treatments:

Annealing:

Class A Steels.—Held at 1650° F. for two hours and cooled in furnace without opening the door but opening few small vents in top of furnace to allow escape of heat.

Class B Steels.—Held at 1600° F. for two hours using the same procedure as for Class A steels.

Normalizing:

Class A Steel.—Held at 1650° F. for two hours and withdrawn from furnace while at this temperature, each bar being quickly placed to one side away from contact with other bars and on the same surface at room temperature, all for the purpose of providing the same cooling operation for each side of every bar and giving it a true normalizing treatment.

Class B Steel.—Held at 1600° F. for two hours using the same procedure as for Class A steel.

Normalizing and Drawing:

Class A Steel.—Held at 1650° F. for two hours. Withdrawn from furnace to cool as described above for normalizing. Reheated to 1150° F. and held at this temperature for $3\frac{1}{2}$ hours and cooled in furnace.

Class B Steel.—Held at 1600° F. for two hours. Withdrawn from furnace to cool as for Class A steel. Reheated to 1250° F. and held at this temperature for $3\frac{1}{2}$ hours and cooled in furnace.

One-third of the bars have now been sent to Watertown Arsenal and another third to Naval Experiment Station, at which tension, impact, compression, fatigue and torsion tests will be made. The remaining third is retained at the Bureau of Standards in case check tests are desired or for special tests.

STUDIES OF EFFECT OF ADDED PHOSPHORUS (SERIES D)

During the year the Association of American Steel Manufacturers suggested the desirability of a series of tests to determine the effect of added phosphorus in low-carbon steel, corresponding to the practice of rephosphorizing in the manufacture of welded steel pipe. The committee concurred in the importance of such a study and has been considering a program in conjunction with the American Petroleum Institute, which is interested in tests of welded steel pipe used in the oil industry. The committee is now working on a program by which its studies, although confined to the determination of effect of phosphorus in low-carbon steel *per se*, will be coordinated with the studies of the Petroleum Institute on pipe itself, the plan being to have furnished to the committee material in the form of 6 by $\frac{5}{8}$-in. plate from five heats of steel with various phosphorus content, the steel from these heats being also fabricated into pipe for tests by the American Petroleum Institute.

This tentative program contemplates a steel of carbon content 0.06 to 0.12 per cent and phosphorus contents of 0.025, 0.04, 0.06, 0.07 and 0.10 per cent; the phosphorus in the first heat being "residual" and in the other four "added." The material will be tested as rolled, in annealed and in quenched conditions. Tension, impact, bend, shear, fatigue and hardness tests will be made on specimens taken parallel with and normal to the direction of rolling.

The details of this program and arrangements for production of the material in accordance therewith are being considered by the committee at its June meeting.

Respectfully submitted on behalf of the Joint Committee,

G. K. BURGESS,
Chairman.

C. L. WARWICK,
Secretary.

JOINT RESEARCH COMMITTEE

ON

EFFECT OF TEMPERATURE ON THE PROPERTIES OF METALS

PROGRESS REPORT TO THE SPONSOR SOCIETIES

Since the last report of the committee, presented at the annual meeting of the Society in 1927,[1] three meetings have been held, at New York, Washington, and Atlantic City. The program outlined in that report is being followed, and the status of the several projects under way is herein briefly reviewed.

The committee reports further progress on short-time and long-time tension tests at elevated temperatures. This work is being carried out by 16 laboratories and manufacturers and their hearty cooperation is acknowledged. While progress may seem slow, the fact is recognized that the laboratories are contributing the work gratis and that their routine work takes precedence. The sub-committee for the analysis and comparison of tests reports considerable progress, and their studies indicate the necessity of careful analysis of the tests and the necessity of establishing standardized methods in order to obtain comparable results from different laboratories.

Arrangements for fatigue tests at elevated temperatures are practically completed. This arrangement is by contract between the University of Illinois Engineering Experiment Station and the sponsor societies. Between one year and 18 months will be required to complete the first phase of the investigation. A fund to cover the anticipated cost has been subscribed by six manufacturers of steam turbines.

A proposition has been obtained from a university to conduct a set of thermal conductivity tests on the five materials already under investigation at a nominal cost. An agreement will be executed for the purpose and the work started at once.

During the year, a sub-committee issued a questionnaire for the purpose of collecting service information on alloy metals at elevated temperatures, and a considerable quantity of data resulted. The results were tabulated in a form which it was thought would be suitable for publication. It was found, however, that some manufacturers considered it unfair to publish such data with the maker openly identified. The tabulation has been recast, and the sub-committee is endeavoring to obtain the approval of the manufacturers for publication in this form.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 139 (1927).

A bibliography containing 307 titles is now available in printed form from the sponsor societies. This bibliography was prepared, edited, and indexed by a sub-committee, with generous cooperation and assistance from the Library personnel of the American Society of Mechanical Engineers, and the Library Division of Henry L. Doherty and Co. It is indexed chronologically, with cross indices by authors and subjects.

Respectfully submitted on behalf of the joint committee,

G. W. SAATHOFF,
Chairman.

F. M. VAN DEVENTER,
Secretary.

REPORT OF RESEARCH COMMITTEE ON YIELD POINT OF STRUCTURAL STEEL

Introduction

As stated in its progress report last year,[1] the committee first attempted to ascertain the effect of speed of loading and method of detecting on the yield point of structural steel. In these studies two series of tests, No. 261 and No. 271 have been conducted by five laboratories. These laboratories are: The Coatesville Laboratory of the Bethlehem Steel Co., the South Works and Gary Laboratories of the Illinois Steel Co., the Materials Laboratories at Rensselaer Polytechnic Institute, and the University of Wisconsin. Through Mr. John Brunner the Illinois Steel Co. cooperated with the committee in the selection and preparation of over six hundred specimens used in these tests. The tests of Series No. 261 were made on three grades of structural steel bars, each grade consisting of very uniform material, whereas the tests of Series No. 271 were made on specimens cut from various parts of selected structural steel shapes in which the metal was more variable in quality. This report presents the principal data secured from the two series of tests.

Material

For Series No. 261 one hundred cylindrical tension specimens 18 in. long and 30 cylindrical compression specimens 4 in. long were milled from $\frac{3}{4}$-in. round rods of each of the following structural steels:

(*a*) Structural steel for bridges (A.S.T.M. Specifications A 7 - 24);

(*b*) Structural nickel steel (A.S.T.M. Specifications A 8 - 24);

(*c*) Structural silicon steel (A.S.T.M. Specifications A 94 - 25 T).

Twenty representative tension specimens selected in accordance with a definite procedure were distributed to each laboratory, and in like manner fifteen compression specimens were furnished each college laboratory.

Mill analyses and tension test data for the steels of Series No. 261 and No. 271 are given in Table I.

For Series No. 271, short lengths of the light and heavy plate, angle, channel and I-beam indicated in Table I were selected. Each length was cut transversely into 5 portions each slightly over 18 in. long. From these 18-in. portions, rectangular tension test specimens 18 in. long and 1 in. wide were cut as indicated in Fig. 1. From a preliminary series of tests on 24 test specimens cut from the toes of a 15-in. 33.9-lb. channel and tested in two of the laboratories, it was ascertained that specimens machined on three faces exhibited practically the same yield points and ultimate strengths as specimens machined on four faces. Accordingly, for tests of Series No. 271 the specimens were machined on two or three faces only. All specimens from a given 18-in. portion were sent to one laboratory in accordance with a definite schedule. Thus each laboratory was provided with 40 test specimens.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 646 (1927).

TABLE I.—DATA FROM MILL TESTS.

SERIES NO. 261, TESTS ON $\frac{3}{4}$-IN. ROUND BARS

Material	Carbon Steel	Nickel Steel	Silicon Steel
TENSION TESTS:			
Heat number	59 275	3 x 6 113	68 434
Reduction in area, per cent	57.83	45.24	60.41
Elongation in 8 in., per cent	28.00	15.88	24.75
Yield Point, lb. per sq. in	41 210	73 120	51 970
Tensile Strength, lb. per sq. in	65 890	109 900	81 740
CHEMICAL ANALYSIS:			
Carbon	0.25	0.40	0.30[a]
Manganese	0.58	0.62	0.80[a]
Phosphorus	0.016	0.022	0.016[a]
Sulfur	0.039	0.024	0.037[a]
Silicon	....	0.240	0.35[a]
Nickel	....	3.36	....

SERIES NO. 271

	Plate		Angle		Channel		I-Beam	
	12 by $\frac{3}{8}$ in.	12 by $\frac{7}{8}$ in.	6 by 6 by $\frac{3}{8}$-in.	6 by 6 by $\frac{7}{8}$-in.	15 in., 35 lb.	15 in., 55 lb.	24 in., 79.9 lb.	24 in., 100 lb.
TENSION TESTS:								
Heat number	929 023	919 733	16 626	21 698	13 581	919 611	15 596	18 548
Elongation in 8 in., per cent	28.12	29.25	29.50	28.00	30.75	28.25	28.62	27.25
Yield Point, lb. per sq. in	37 210	35 900	38 960	34 660	37 470	37 965	36 580	37 060
Tensile Strength, lb. per sq. in	60 900	61 530	63 540	56 500	57 780	58 950	63 430	62 630
Pulling speed, in. per minute	$\frac{1}{2}$ at yield point, $7\frac{11}{16}$ to rupture							
CHEMICAL ANALYSIS:								
Carbon	0.16	0.20	0.20	0.16	0.15	0.21	0.20	0.25
Manganese	0.43	0 52	0.45	0.40	0.40	0.39	0.50	0.36
Phosphorus	0.029	0.017	0.012	0.010	0.011	0.010	0.013	0.012
Sulfur	0.045	0.032	0.026	0.027	0.030	0.032	0.038	0.042

[a] Values are ladle analyses; all others are check analyses.

METHOD OF TESTING

The machines used in these tests were all screw-gear driven and had lever weighing systems. Capacities varied from 60,000 to 200,000 lb. All machines were calibrated prior to each series of tests. They were all accurate within 1 per cent for the loading range used and sensitive to a change in load of 50 lb. when loaded to 40,000 lb.

The areas of specimens were calculated from average cross-sectional dimensions taken to the nearest 0.001 in. at or near mid-sections. The areas of specimens of Series No. 271 were also calculated from the measured length and weight. These data indicated that the areas calculated from weights averaged approximately 0.4 per cent smaller than the measured areas.

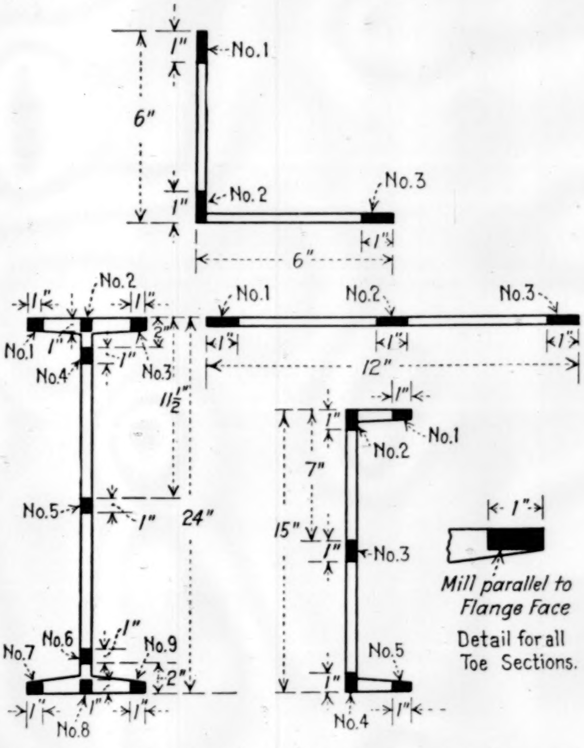
1"
No.1
6"
1"
No.2
No.3
1"
6"
No.2
1"
1"
No.1
1"
2"
No.4
1"
No.3
11½"
No.5
1"
24"
No.7
No.6
1"
No.9
2"
1"
1"
1"
No.8
No.1
No.2
No.3
1"
1"
1"
12"
1"
1"
No.1
No.2
7"
15"
1"
No.3
No.5
1"
No.4
1"
1"
Mill parallel to
Flange Face
Detail for all
Toe Sections.

FIG. 1.—Showing Positions of Tensile Specimens for Tests of Series 271.

Tension specimens were gripped with serrated wedges and loaded with any controllable speed to three-fourths of the estimated yield point. The desired speed was then applied until the yield point had been found. The remainder of each test was run at speeds not over 2.0 in. per minute.

The yield point was detected by the following methods:

(*a*) *Drop of beam.*—The scale beam was kept in balance and the load recorded at which the first definite halt in movement of poise along the beam occurred. The momentary drop of beam due to overstrain at the grips was disregarded.

(*b*) *Scaling.*—Record was made of the load at which the mill scale fell from the middle of the test specimen. (At Rensselaer and Coatesville some of the machined specimens were coated with chalk to assist in making this determination.)

(*c*) *Multiplying dividers.*—By means of multiplying dividers with an 8-in. gage and multiplication of 5 to 1 or greater, the load corresponding to a strain of 0.5 per cent was determined.

(*d*) *Strain gage.*—In the tests of Series No. 261 strain gages reading to 0.0002 in. or less were used on 2-in. gage lengths. The lowest load at which there was visible acceleration in the rate of motion of the dial hand on the gage was recorded.

In making the compression tests of Series No. 261, spherical bearing blocks surmounted the specimens. The radii of curvature of the blocks used at Rensselaer and at Wisconsin were 5 in. and 1 in., respectively. Dividers used in these tests had 2-in. gage lengths and 10 to 1 multiplications.

RESULTS OF TESTS OF SERIES NO. 261

Uniformity of Material.—To arrive at an estimate of the uniformity in tensile strength of the bar steel used in Series No. 261, the probable error for each group of 100 tests was calculated. Basing calculations on results from all laboratories, the probable error of a single determination was 1.0 per cent for carbon steel, 1.2 per cent for nickel steel, and 2.0 per cent for silicon steel. For carbon steel the maximum deviation of a single specimen from the grand mean tensile strength for all specimens was 4 per cent, and 79 per cent were within 2 per cent of the mean. For nickel steel the same results obtained. For silicon steel the maximum deviation of a single determination was 6 per cent, and 48 per cent were within 2 per cent of the grand mean tensile strength.

Study of the tensile strength data for specimens tested at yield point under different speeds showed that the percentage variation in the tensile strength was approximately the same for the specimens so tested. Considering the average tensile strengths for the specimens of a single steel tested in a given laboratory, it was found that the greatest percentage deviation of such average from the mean of all specimens of that steel was only 1 per cent. The averages of such deviations of averages from the means were 0.55, 0.51, and 0.62 per cent for the carbon, nickel and silicon steels, respectively.

From the data on percentage of elongation in 8 in., the maximum deviation of a single determination from the grand mean of all was 21 per cent. This occurred in the carbon steel group. For the carbon, nickel, and silicon steels the percentages of results within 10 per cent of the grand mean were 93, 91, and 89, respectively. The variations for the percentage of reduction in area were slightly greater than for the percentage of elongation.

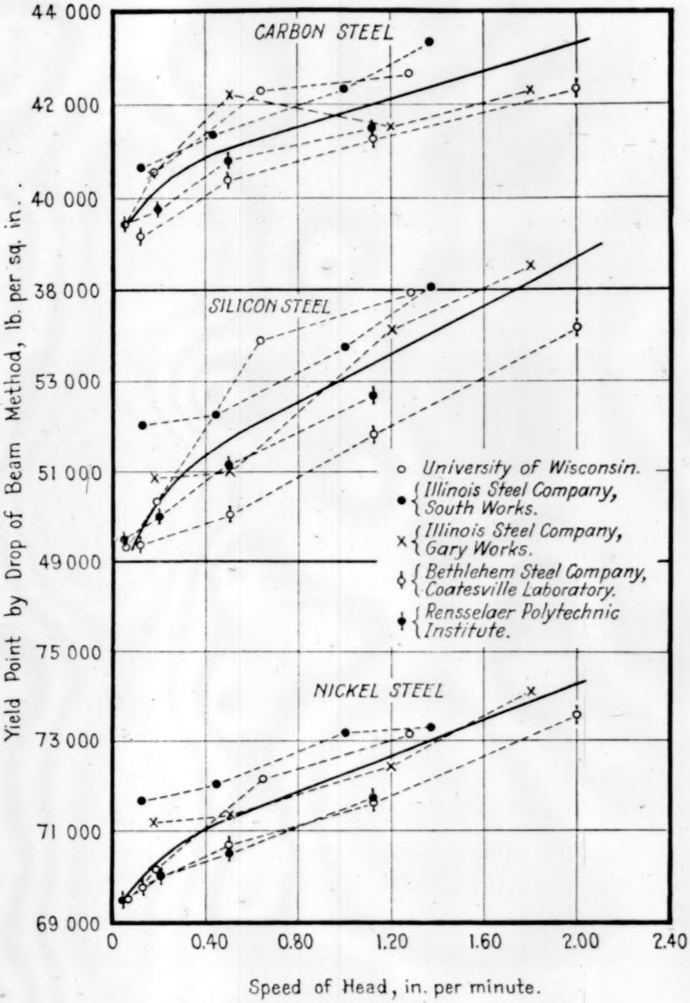

FIG. 2.—Effects of Speed of Machine on Yield Point of Carbon, Silicon, and Nickel Steels of Series No. 261.

TABLE II.—RESULTS OF TENSION TESTS OF SERIES NO. 261.

Each Value is the Average of 5 Tests

Laboratory and Machine	Kind of Steel	Speed of Head at Yield Point, in. per minute	Tensile Strength, lb. per sq. in.	Yield Point, lb. per sq. in.				Elongation in 8 in., per cent	Reduction of Area, per cent
				Drop-of-Beam Method	Scaling Method	Divider Method	Strain Gage Method		
University of Wisconsin, 200,000-lb., 3-screw Riehlé Machine.	Carbon	0.06	65 790	39 420	39 420	39 770	39 640	28.6	59.9
		0.18	66 150	40 550	40 490	40 650	40 800	28.0	59.9
		0.64	66 050	42 280	42 080	42 080	42 450	30.3	59.4
		1.28	65 490	42 610	42 590	42 610	42 610	28.5	60.4
	Nickel	0.06	109 680	69 480	......	69 480	69 480	18.5	50.4
		0.18	109 380	70 150	......	70 150	70 150	16.4	46.8
		0.64	110 240	72 180	......	72 180	72 180	16.8	47.9
		1.28	110 300	73 160	......	73 160	73 160	17.3	48.3
	Silicon	0.06	81 420	49 300	50 060	50 410	50 430	24.6	59.2
		0.18	81 580	50 360	50 760	51 010	51 200	24.6	61.0
		0.64	83 390	53 870	53 870	53 870	53 870	23.2	56.0
		1.28	83 020	54 950	54 950	54 950	54 950	23.3	56.8
Illinois Steel Co., South Works, 200,000-lb., 2-screw Riehlé Machine.	Carbon	0.125	66 200	40 670	40 670	40 670	......	28.5	59.3
		0.44	66 420	41 390	40 400	41 390	......	27.5	56.7
		1.00	65 290	42 330	42 330	42 330	......	28.9	56.3
		1.375	66 030	43 370	43 370	43 370	......	27.2	58.2
	Nickel	0.125	110 040	71 630	71 630	71 630	......	16.4	41.7
		0.44	109 920	72 030	......	72 030	......	16.0	49.7
		1.00	109 800	73 170	......	73 170	......	17.7	45.7
		1.375	110 060	73 220	......	73 220	......	16.8	46.7
	Silicon	0.125	82 410	52 030	52 030	52 030	......	23.5	55.0
		0.44	80 780	52 230	52 230	52 230	......	24.3	54.2
		1.00	82 860	53 750	53 750	53 750	......	23.6	55.6
		1.375	81 510	55 070	55 070	55 070	......	24.1	57.3
Illinois Steel Co., Gary Works, 200,000-lb., 4-screw Olsen Machine.	Carbon	0.17	65 520	40 530	40 530	40 530	......	29.3	60.6
		0.50	66 350	42 190	42 190	42 190	......	27.7	59.5
		1.20	66 040	41 530	41 530	41 530	......	28.5	60.7
		1.80	65 420	42 290	42 290	42 290	......	27.9	61.0
	Nickel	0.17	110 700	71 160	......	71 160	......	17.9	50.4
		0.50	110 010	71 360	......	71 360	......	16.8	49.8
		1.20	111 230	72 440	......	72 440	......	17.5	49.5
		1.80	111 100	74 090	......	74 090	......	16.4	48.8
	Silicon	0.17	82 030	50 860	50 860	50 860	......	25.0	60.4
		0.50	81 750	51 050	51 050	51 050	......	25.5	61.0
		1.20	83 600	54 180	54 180	54 180	......	23.9	57.2
		1.80	83 540	55 500	55 500	55 500	......	23.7	56.7
Bethlehem Steel Co., Coatesville Laboratory, 100,000-lb., 4-screw Olsen Machine.	Carbon	0.125	65 460	39 990	38 580	39 680	......	28.8	60.0
		0.50	65 520	41 090	40 230	40 320	......	28.4	60.2
		1.125	65 220	41 680	41 160	41 160	......	28.3	60.5
		2.00	64 950	42 340	42 340	42 340	......	29.1	62.9
	Nickel	0.125	109 340	69 840	76 480	69 730	......	17.3	49.7
		0.50	109 140	70 680	75 060	70 680	......	17.2	50.2
		1.125	109 080	71 620	77 080	71 620	......	18.0	49.5
		2.00	109 780	73 530	78 040	73 530	......	17.1	50.0
	Silicon	0.125	80 880	50 090	49 370	49 970	......	23.9	60.5
		0.50	80 520	51 530	50 420	51 120	......	24.7	61.2
		1.125	82 500	52 140	51 820	52 200	......	23.8	58.9
		2.00	82 580	54 110	54 110	54 110	......	23.7	57.8
Rensselaer Polytechnic Institute, 60,000-lb., 3-screw Olsen Machine.	Carbon	0.05	64 640	39 430	39 220	39 400	39 400	28.4	60.9
		0.20	65 390	39 780	39 690	39 780	39 990	28.7	57.9
		0.50	64 690	40 800	39 970	40 370	40 370	29.4	59.3
		1.12	65 330	41 450	41 450	41 450	41 450	28.5	58.4
	Nickel	0.05	108 230	69 450	80 200	68 880	68 860	16.9	49.7
		0.20	108 380	70 020	78 120	69 680	70 020	18.0	48.3
		0.50	108 440	70 500	71 420	70 230	70 230	17.4	46.6
		1.12	109 000	71 690	76 880	71 690	71 690	17.3	45.2
	Silicon	0.05	80 760	49 480	49 110	49 700	49 700	25.1	59.9
		0.20	80 320	50 030	49 760	50 030	50 030	24.0	58.0
		0.50	81 920	51 180	51 040	51 180	51 180	24.3	56.6
		1.12	81 920	52 680	50 160	52 770	52 770	24.3	57.8

Considering the above data it is apparent that the specimens of a given steel were very uniform both in strength and ductility.

Effect of Speed on Yield Point (Drop of Beam Method).—The general relationship between yield point in tension by drop of beam and speed of loading for the tests of Series No. 261 is shown in Fig. 2 which was plotted from the data in Table II.

From the yield point - speed curves for the different laboratories, it appears that in all cases the yield point increased with speed of loading. The rate of increase was quite variable and appears to have depended upon the machine used. From the mean curves for all laboratories, the average increase in yield point in tension corresponding to a speed change from 0.05 to 2.0 in. per minute was:

Carbon steel	3900 lb. per sq. in., or 9 per cent
Nickel steel	4800 lb. per sq. in., or 7 per cent
Silicon steel	6500 lb. per sq. in., or 12 per cent

The rate of change of yield point due to change in speed was greater at speeds below 0.5 in. per minute than for speeds above 0.5 and less than 2.0 in. per minute. The average curves indicate that with a loading speed of 0.20 in. per minute the yield point by drop of beam was 600 to 1000 lb. per sq. in. higher than with a speed of 0.05 in. per minute. Considering averages of five specimens tested in different laboratories at approximately the same speed, the following maximum ranges in these averages may be obtained from Fig. 2:

	MAXIMUM RANGE
Carbon steel at ⅛ in. per minute	1600 lb. per sq. in., or 4 per cent
Carbon steel at ½ in. per minute	1850 lb. per sq. in., or 5 per cent
Nickel steel at ⅛ in. per minute	2000 lb. per sq. in., or 3 per cent
Nickel steel at ½ in. per minute	1600 lb. per sq. in., or 2 per cent
Silicon steel at ⅛ in. per minute	2700 lb. per sq. in., or 5 per cent
Silicon steel at ½ in. per minute	2800 lb. per sq. in., or 5 per cent

If all speeds and laboratories are considered, the maximum ranges in these average yield points for five specimens were:

	MAXIMUM RANGE
Carbon steel	4210 lb. per sq. in., or 10 per cent
Nickel steel	4640 lb. per sq. in., or 6 per cent
Silicon steel	6200 lb. per sq. in., or 11 per cent

The maximum ranges in yield point by drop of beam for individual specimens tested in different laboratories at the same speed were:

	MAXIMUM RANGE
Carbon steel at ⅛ in. per minute	3300 lb. per sq. in., or 8 per cent
Carbon steel at ½ in. per minute	3500 lb. per sq. in., or 9 per cent
Nickel steel at ⅛ in. per minute	4500 lb. per sq. in., or 6 per cent
Nickel steel at ½ in. per minute	4500 lb. per sq. in., or 6 per cent
Silicon steel at ⅛ in. per minute	4200 lb. per sq. in., or 8 per cent
Silicon steel at ½ in. per minute	4000 lb. per sq. in., or 8 per cent

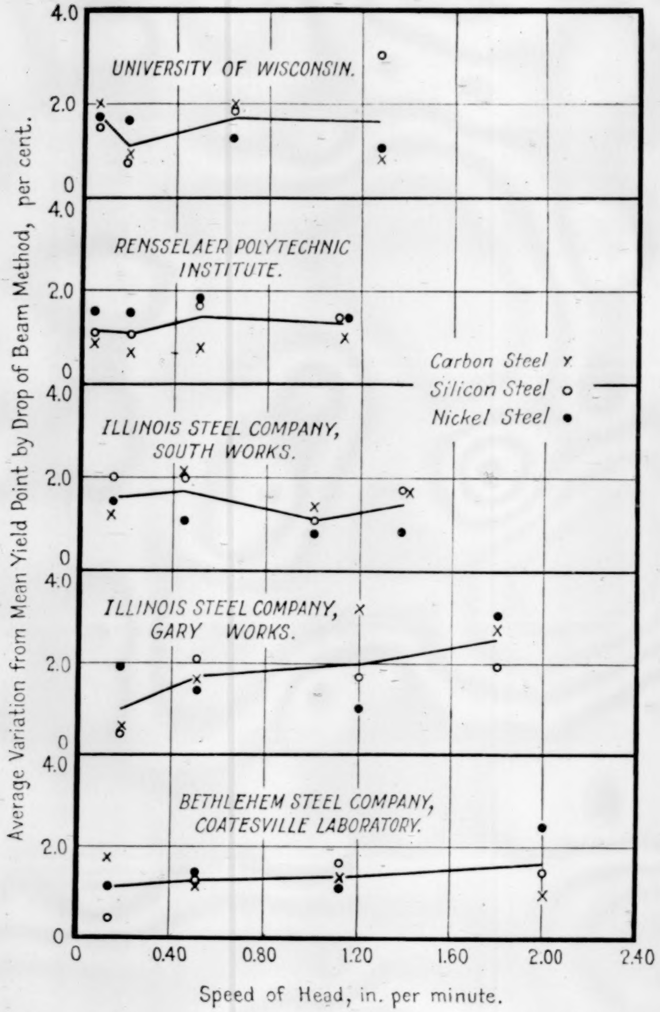

FIG. 3.—Relationship Between Variation in Yield Point by Drop-of-Beam Method and Speed of Machine, Series No. 261.

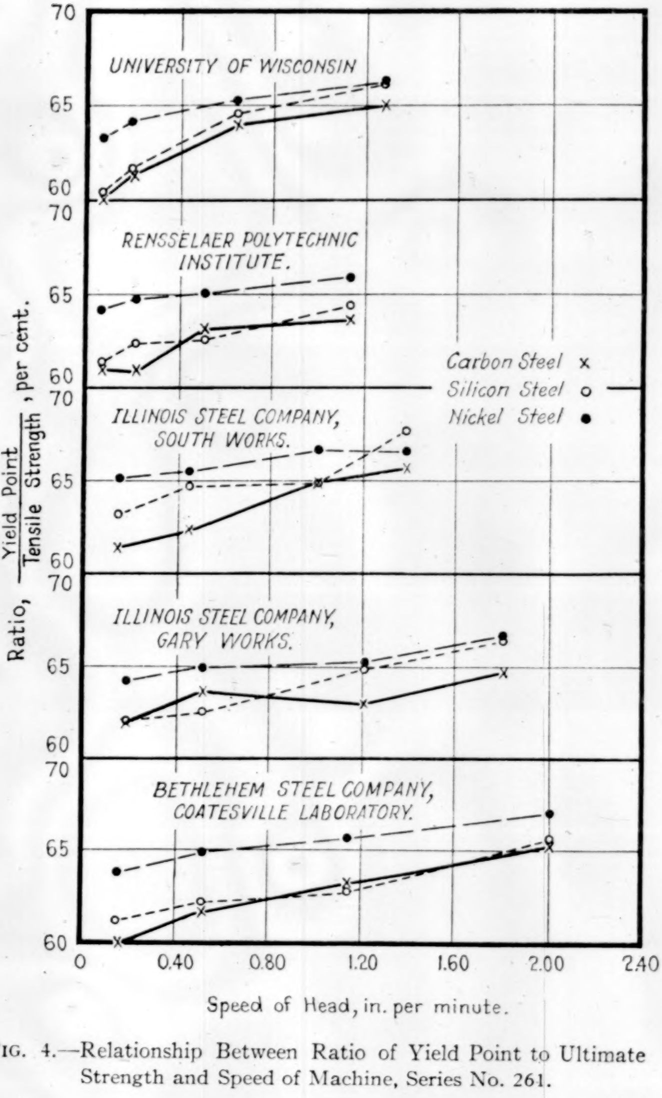

FIG. 4.—Relationship Between Ratio of Yield Point to Ultimate Strength and Speed of Machine, Series No. 261.

The maximum ranges in yield point for individual specimens, all speeds considered, were:

	MAXIMUM RANGE
Carbon steel	6 100 lb. per sq. in., or 15 per cent
Nickel steel	10 100 lb. per sq. in., or 14 per cent
Silicon steel	9 100 lb. per sq. in., or 17 per cent

In Fig. 3 is shown the average percentage variation from the mean yield point by drop of beam of every group of five specimens tested. Considering all laboratories, speed of loading had little effect on these average percentage variations. In most cases the average percentage variation for a group of five specimens was between 1 and 2.

Data secured at the Coatesville laboratory (100,000-lb. machine) showed that with the carbon and silicon steels at speeds of 0.5 in. per minute or less there was a perceptible drop of beam due to combined stress at the grips which occurred at loads approximately 2 per cent lower than the loads at which the second drop of beam occurred. The latter loads closely corresponded to the yield point indicated both by dividers and by scaling. Other laboratories also noted similar phenomena.

TABLE III.—COMPARISON OF UNIFORMITY OF METHODS FOR DETECTION OF YIELD POINT.

Laboratory and Machine	Mean of Percentage Deviations from Means			
	Drop-of-Beam Method	Divider Method	Scaling Method	Strain Gage Method
University of Wisconsin, 200,000-lb., 3-screw Machine	1.54	1.38	1.50	1.49
Illinois Steel Co., South Works, 200,000-lb. Machine	1.43	1.43	1.77	....
Illinois Steel Co., Gary Works, 200,000-lb. Machine	1.80	1.80	1.78	....
Bethlehem Steel Co., Coatesville Laboratory, 100,000-lb. Machine	1.23	1.31	1.23	....
Rensselaer Polytechnic Institute, 60,000-lb. Machine	1.26	1.11	1.43	1.18
Grand Mean	1.45	1.41	1.54	....
Mean, University of Wisconsin and Rensselaer Polytechnic Institute	1.40	1.24	1.46	1.34

That the ratio $\frac{\text{yield point by drop of beam}}{\text{tensile strength}}$ increased with speed of loading at yield point is shown by Fig. 4.

Comparison of Methods for Determining Yield Point.—In the lower portion of Fig. 5, ratios $\frac{\text{yield point by dividers}}{\text{yield point by drop of beam}}$ are shown plotted against speed of loading. This ratio was unity in the tests made at two of the mill laboratories, averaged slightly below one for one mill and one college laboratory, and slightly above unity for the other college laboratory. The mean ratio for all tests was 1.000. Considering ratios of averages for five specimens, the range was 0.98 to 1.02.

Comparing Figs. 3 and 6, and referring to Table III, it will be seen that the divider method of determining the yield point gave results slightly less variable than the drop of beam method. Also there was less variation in tests made on lighter machines than in those made on the heavier machines.

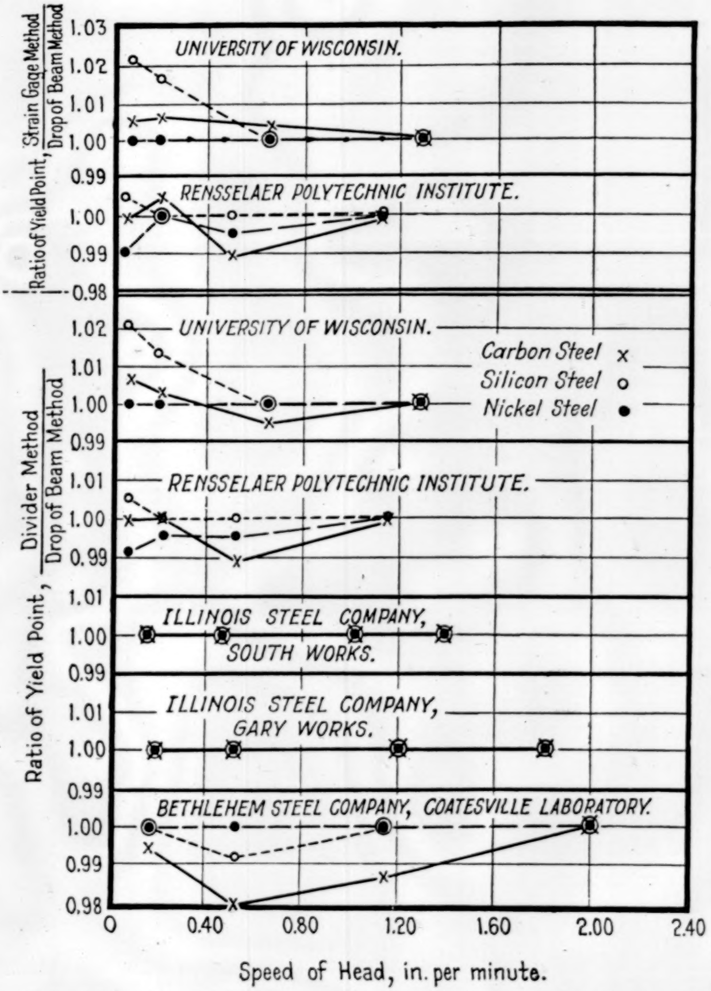

FIG. 5.—Relationship of Divider and Strain Gage Method Indications to Drop-of-Beam Method Indications of Yield Point for Speeds Used in Series No. 261.

The determination of the load at which the scale fell from the middle of the specimen was not a satisfactory method with the nickel-steel specimens. With the other steels it was no more reliable than the drop of beam method. For the carbon steels the yield point by

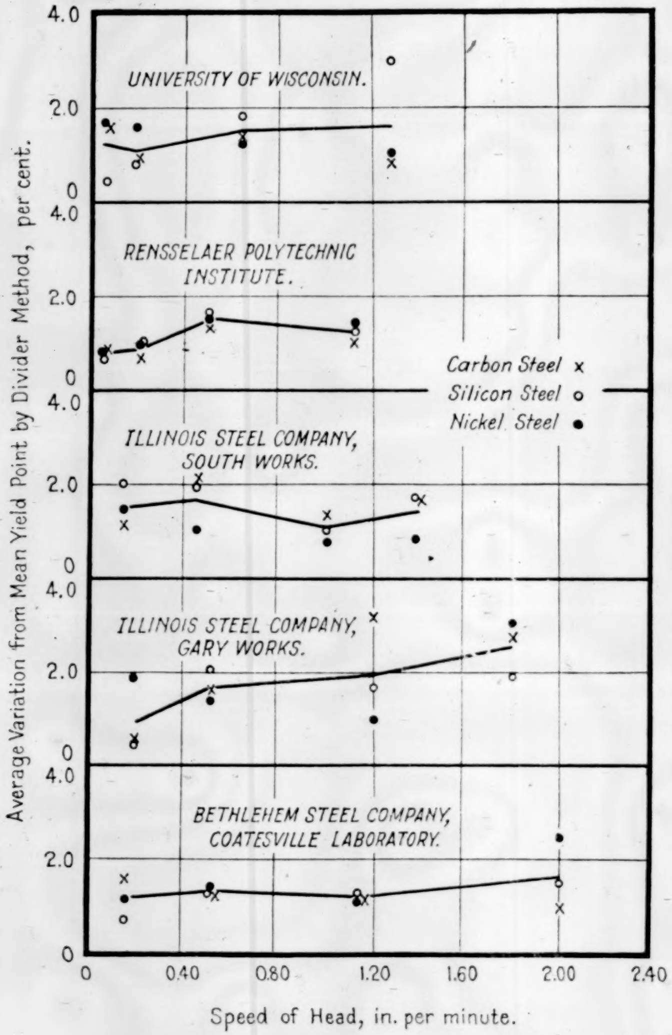

FIG. 6.—Relationship Between Variation in Yield Point by Divider Method and Speed of Machine, Series No. 261.

scaling averaged 250 lb. per sq. in. less than the yield point by drop of beam. For the silicon steel the yield point by drop of beam averaged 75 lb. per sq. in. higher than the yield point by scaling.

The upper portion of Fig. 5 shows the relationship of the ratio $\frac{\text{yield point by strain gage}}{\text{yield point by drop of beam}}$ to speed of loading at yield point. The diagrams are similar to those for the same laboratories in the lower portion of the figure. Data in Table III indicate that there was more variation in yield points determined by 2-in. strain gages than in the yield points obtained from 8-in. divider indications.

Effect of Speed of Loading on Compression Yield Point.—Table IV shows the results of compression tests made on 4 by $\frac{3}{4}$-in. cylinders at Rensselaer and Wisconsin. These data do not show consistent relationships between yield point and speed of loading. The Wisconsin tests indicate that the yield point in compression by drop of beam increased with speed in approximately the same manner as the yield point in tension, provided speed per inch of free length of specimen is considered in making the comparison. For carbon steels only, the Rensselaer results indicate an increase in yield point with speed of loading. For the other steels tested at that laboratory, the yield point decreased with the increase in speed.

Table IV.—Results of Compression Tests of Series No. 261.

Each Value is the Average of 5 Tests

Laboratory and Machine	Kind of Steel	Speed of Head at Yield Point, in. per minute	Compressive Strength, lb. per sq. in.	Yield Point, lb. per sq. in.			
				Drop-of-Beam Method	Scaling Method	Divider Method	Strain Gage Method
University of Wisconsin, 200,000-lb., 3-screw Riehlé Machine.	Carbon	0.03	65 020	41 130	41 290	41 290	41 290
		0.06	65 790	42 060	41 720	42 110	40 070
		0.18	62 570	43 070	38 290	41 970	41 970
	Nickel	0.03	109 340	72 970	......	72 970	73 370
		0.06	110 840	74 130	......	74 130	74 130
		0.18	111 180	75 480	......	75 480	75 480
	Silicon	0.30	80 980	51 830	46 180	51 830	51 830
		0.06	81 340	52 600	51 280	52 600	52 600
		0.18	82 400	54 310	53 030	54 310	54 310
Rensselaer Polytechnic Institute, 60,000-lb., 3-screw Olsen Machine.	Carbon	0.05	......	39 480	39 010	39 480	39 480
		0.06	......	39 420	38 050	39 420	39 420
		0.12	......	40 870	40 510	40 510	40 870
	Nickel	0.05	......	70 050	70 330	70 050	70 050
		0.06	......	69 610	69 870	69 580	69 610
		0.12	......	68 480	69 850	68 480	68 480
	Silicon	0.05	......	52 090	51 520	51 480	52 090
		0.06	......	50 360	48 360	49 060	50 360
		0.12	......	50 510	49 070	50 300	50 300

Scaling again proved unsatisfactory as an index of yield point of the nickel steel. With the other steels it was a less reliable indication of yield point than in the tension tests. In most of the groups of compression tests, yield point loads by scaling exhibited more variation from the mean than those obtained by any of the methods tried. In these short prisms inequalities in end bearings were probably the chief cause of such discrepancies.

Owing to the fact that the divider and the strain gage indications were obtained on one surface element of the specimen, these indications did not furnish criteria of overstrain at the axis of the specimen. Hence it is doubtful if they were as satisfactory indices of yield point as the drop of beam, especially at the slower speeds of loading.

Comparison of Yield Points in Tension with Yield Points in Compression.—Based on comparable rates of strain in both kinds of test, the average ratio $\frac{\text{yield point in tension}}{\text{yield point in compression}}$ was for the Wisconsin tests 0.96, 0.95 and 0.96 for the carbon, nickel, and silicon steels, respectively. In the Rensselaer tests the ratios for the steels in the same order were 0.97, 1.02 and 0.99.

TABLE V.—AVERAGE STRENGTH PROPERTIES OF SPECIMENS CUT FROM STRUCTURAL STEEL SHAPES, SERIES NO. 271.

	Laboratory No. 2, Rensselaer Polytechnic Institute	Laboratory No. 1, University of Wisconsin	Laboratory No. 3, Illinois Steel Co., South Works	Laboratory No. 5, Bethlehem Steel Co., Coatesville Laboratory	Laboratory No 4, Illinois Steel Co., Gary Works	Mean Values
Yield Point, Drop of Beam Method, lb. per sq. in.	34 074	34 183[b]	36 370	35 034	37 133	35 359
Yield Point, Divider Method, lb. per sq. in.	34 412	35 008	36 465	35 237	37 133	35 651
Yield Point, Scaling Method, lb. per sq. in.	36 657[a]	38 892[c]	36 465	36 939	37 133	37 217
Tensile Strength, lb. per sq. in.	58 594	58 088	58 898	57 671	58 674	58 385
Speed to Yield Point, in. per minute	1.20	0.64	0.44	0.50	1.20	......
Speed at Yield Point, in. per minute	0.05	0.18	0.44	0.50	1.20	......
Speed, Yield Point to Rupture, in. per minute	1.20	1.28	1.38	1.12	1.20	......
Time, Zero Load to Failure, minutes and seconds	....	5–40	3–25	4–18	3–13	......
Time or Test, minutes and seconds	5–15	7–54	6–39	....	7–42	......

[a] Average for 25 tests.
[b] Average for 37 tests.
[c] Average for 34 tests.

RESULTS OF TESTS OF SERIES NO. 271

Quality of Material.—Since the specimens for this series of tests were taken from eight different heats and also from different parts of rolled shapes, they included variables in composition and in mechanical work which were not present in the specimens from a given steel of Series No. 261. Table V shows the average strength properties of the specimens tested at each laboratory. The range in the five average tensile strengths is 2 per cent.

Considering variations from the grand mean ultimate, 58,385 lb. per sq. in., in Table VI we find 73 per cent of the tensile strengths are within 5 per cent of the grand mean and 94 per cent are within 10 per cent of the grand mean. Most of the high strengths were obtained with specimens from roots of I-beams and the root of the light angle. The specimens from the roots of the light channel exhibited the lowest strengths.

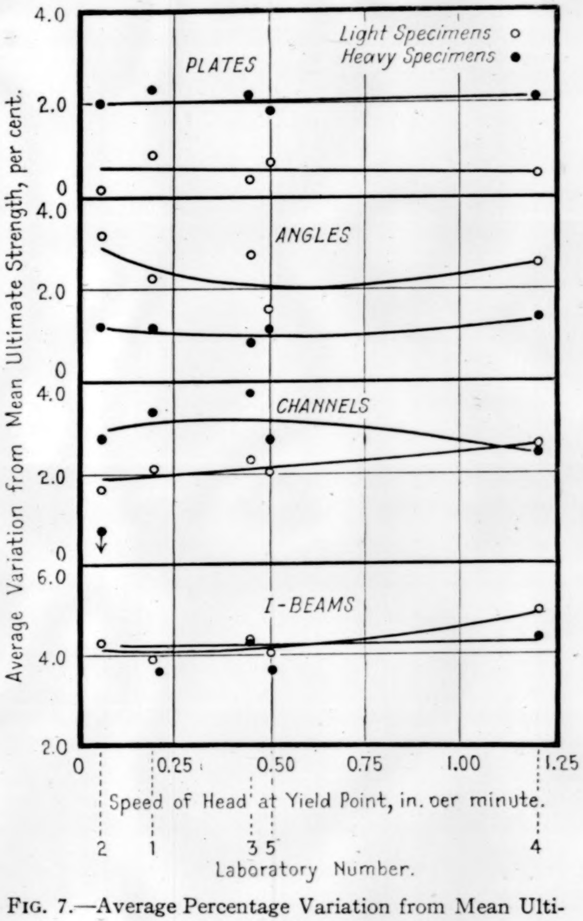

Fig. 7.—Average Percentage Variation from Mean Ultimate Strength, Series No. 271.

Figure 7 shows the average percentage variation in tensile strength for the specimens of each shape tested at a given laboratory under a given speed. There appears to be no well-defined relation

TABLE VI.—RESULTS OF TENSION TESTS OF SERIES NO. 271.

Shape	Laboratory	Speed of Head at Yield Point, in. per minute	Specimen Number	Specimen Location[a]	Tensile Strength, lb. per sq. in.	Yield Point, lb. per sq. in.			Elongation in 8 in., per cent	Reduction of Area, per cent
						Drop-of-Beam Method	Sealing Method	Divider Method		
Plate, 12 by $\frac{3}{8}$ in.	No. 2	0.05	P-21	Edge...	58 240	34 410	35 500	35 230	29.0	59.2
	No. 2	0.05	P-23		58 060	35 250	35 390	35 390	27.0	54.8
	No. 1	0.18	P-11		59 670	36 510	36 270	36 510	26.8	60.5
	No. 1	0.18	P-13		58 670	35 080	32 820	35 080	26.8	59.7
	No 3	0.44	P-31		59 180	37 190	37 190	37 190	31.2	61.6
	No. 3	0.44	P-33		58 590	37 800	37 800	37 800	29.5	62.2
	No. 5	0.50	P-51		58 070	36 770	36 770	37 010	25.5	63.7
	No. 5	0.50	P-53		58 990	35 140	33 850	33 850	22.8	63.5
	No 4	1.20	P-41		60 820	36 680	36 680	36 680	28.0	57.3
	No 4	1.20	P-43		60 010	37 880	37 880	37 880	26.2	59.1
	Mean..	....	....	....	59 030	36 270	36 015	36 260	27.3	60.2
	No. 2	0.05	P-22	Center.	58 120	33 110	33 410	33 410	28.5	55.6
	No. 1	0.18	P-12		58 430	34 700	33 200	34 700	28.2	62.2
	No 3	0.44	P-32		58 970	36 140	36 140	36 140	30.5	65.2
	No. 5	0.50	P-52		57 980	35 230	36 050	36 050	28.2	59.3
	No 4	1.20	P-42		60 450	36 980	36 980	36 980	28.0	60.1
	Mean..	....	....	....	58 790	35 230	35 155	35 455	28.7	60.5
Plate, 12 by $\frac{7}{8}$ in.	No. 2	0.05	P-71	Edge...	61 470	30 650	30 680	30 650	30.0	58.6
	No. 2	0.05	P-73		61 750	30 540	30 540	30 540	29.8	59.3
	No. 1	0.18	P-61		61 690	31 830	31 830	32 280	23.9	59.0
	No. 1	0.18	P-63		61 405	31 740	31 740	31 740	31.0	59.8
	No. 3	0.44	P-81		62 400	32 870	32 870	32 870	28.5	56.7
	No. 3	0.44	P-83		62 050	33 270	33 270	33 270	29.8	59.4
	No. 5	0.50	P-101		60 940	32 610	32 610	32 610	33.2	59.9
	No. 5	0.50	P-103		60 810	32 740	32 740	32 740	35.2	59.9
	No. 4	1.20	P-91		61 610	33 930	33 930	33 930	31.0	58.2
	No. 4	1.20	P-93		61 500	34 060	34 060	34 060	33.0	61.1
	Mean..	....	....	....	61 560	32 425	32 425	32 530	30.5	59.2
	No. 2	0.05	P-72	Center.	58 820	27 660	28 710	28 070	28.4	59.6
	No 1	0.18	P-62		58 375	27 235	27 235	27 630	30.8	60.6
	No. 3	0.44	P-82		59 220	28 340	32 150	32 150	31.0	60.8
	No 5	0.50	P-102		58 380	29 810	29 810	29 810	33.2	60.2
	No. 4	1.20	P-92		58 660	31 910	31 910	31 910	32.5	60.3
	Mean..	....	....	....	58 690	28 990	29 965	29 915	31.2	60.3
Angle, 6 by 6 by $\frac{3}{8}$ in.	No. 2	0.05	L-21	Toe....	59 700	35 830	35 960	35 960	27.9	58.6
	No. 2	0.05	L-23		58 950	35 400	35 790	35 790	26.5	60.1
	No. 1	0.18	L-11		59 005	37 065	37 065	37 065	25.4	61.6
	No. 1	0.18	L-13		59 040	37 580	37 580	37 580	26.8	64.3
	No. 3	0.44	L-31		60 250	38 880	38 880	38 880	26.0	64.1
	No. 3	0.44	L-33		59 220	37 920	37 920	37 920	26.2	54.2
	No. 5	0.50	L-51		59 660	37 860	39 740	39 740	26.8	60.5
	No. 5	0.50	L-53		58 660	37 530	36 750	36 750	24.8	56.8
	No. 4	1.20	L-41		61 580	41 830	41 830	41 830	26.2	59.0
	No. 4	1.20	L-43		59 820	39 120	39 120	39 120	24.8	59.5
	Mean..	....	....	....	59 590	37 900	38 065	38 065	26.1	59.9
	No. 2	0.05	L-22	Root...	63 660	41 630	49 970	41 880	22.1	55.8
	No. 1	0.18	L-12		62 040	40 960	46 080	40 960	20.8	59.8
	No. 3	0.44	L-32		63 490	42 500	42 500	42 500	25.2	60.2
	No. 5	0.50	L-52		61 260	42 350	42 350	42 350	....	60.0
	No. 4	1.20	L-42		64 180	46 840	46 840	46 840	21.5	59.2
	Mean..	....	....	....	62 925	42 855	45 550	42 905	22.4	59.0

[a] See Fig. 1.

TABLE VI.—RESULTS OF TENSION TESTS OF SERIES NO. 271 (*Continued*).

Shape	Laboratory	Speed of Head at Yield Point, in. per minute	Specimen Number	Specimen Location[a]	Tensile Strength, lb. per sq. in.	Yield Point, lb. per sq. in.			Elongation in 8 in., per cent	Reduction of Area, per cent
						Drop-of-Beam Method	Sealing Method	Divider Method		
Angle, 6 by 6 by $\frac{7}{8}$ in.	No. 2	0.05	L-71	Toe....	56 070	30 750	......	30 950	29.2	57.8
	No. 2	0.05	L-73		55 860	30 500	......	30 500	28.5	58.0
	No. 1	0.18	L-61		55 520	31 340	53 800	31 340	31.2	62.4
	No. 1	0.18	L-63		55 265	29 750	48 515	30 620	32.1	58.8
	No. 3	0.44	L-81		56 640	34 390	34 390	34 390	29.2	62.3
	No. 3	0.44	L-83		56 540	32 030	32 030	32 030	29.2	63.2
	No. 5	0.50	L-101		55 760	32 270	32 270	32 270	33.0	62.6
	No. 5	0.50	L-103		55 220	31 330	34 910	31 330	33.0	61.8
	No. 4	1.20	L-91		56 130	33 730	33 730	33 730	35.2	61.2
	No. 4	1.20	L-93		55 680	33 470	33 470	33 470	30.5	61.9
	Mean..	....	....	....	55 875	31 955	37 890	32 063	31.1	61.0
	No. 2	0.05	L-72	Root...	54 460	30 010	......	30 080	30.2	56.3
	No. 1	0.18	L-62		53 920	......	......	30 730	34.5	58.9
	No. 3	0.44	L-82		55 560	31 510	31 510	31 510	28.8	50.3
	No. 5	0.50	L-102		54 130	29 000	30 530	29 000	31.0	56.7
	No. 4	1.20	L-92		54 280	31 380	31 380	31 380	30.5	54.9
	Mean..	....	....	....	54 470	30 475	31 140	30 540	31.0	55.5
Channel, 15 in., 35 lb.	No. 2	0.05	C-21	Toe....	55 880	36 720	......	38 410	20.2	59.2
	No. 2	0.05	C-25		56 090	38 470	......	39 230	20.8	59.0
	No. 1	0.18	C-11		55 420	37 620	......	38 910	24.4	65.6
	No. 1	0.18	C-15		55 830	37 790	37 790	39 260	19.5	63.9
	No. 3	0.44	C-31		56 240	39 700	39 700	39 700	26.2	66.4
	No. 3	0.44	C-35		57 000	40 500	40 500	40 500	23.8	67.0
	No. 5	0.50	C-51		54 920	39 300	40 720	39 300	19.5	67.1
	No. 5	0.50	C-55		55 200	39 280	39 800	39 280	23.8	64.0
	No. 4	1.20	C-41		57 680	42 320	42 320	42 320	17.8	62.1
	No. 4	1.20	C-45		55 550	41 210	41 210	41 210	19.8	65.0
	Mean..	....	....	....	55 980	39 290	40 290	39 810	21.6	63.9
	No 2	0.05	C-22	Root...	53 720	34 010	34 010	34 010	29.4	59.8
	No. 2	0.05	C-24		54 400	33 780	33 880	33 780	23.8	59.4
	No. 1	0.18	C-12		52 650	33 915	33 915	33 915	31.8	67.4
	No. 1	0.18	C-14		53 010	34 825	34 825	34 825	26.1	66.7
	No. 3	0.44	C-32		53 870	36 770	36 770	36 770	27.0	65.2
	No. 3	0.44	C-34		53 200	35 700	35 700	35 700	27.8	65.4
	No. 5	0.50	C-52		52 780	36 230	36 230	34 060	23.0	66.5
	No. 5	0.50	C-54		52 240	34 740	34 900	34 900	28.8	68.6
	No. 4	1.20	C-42		53 000	37 290	37 290	37 290	30.5	64.4
	No. 4	1.20	C-44		53 870	37 560	37 560	37 560	21.5	64.4
	Mean..	....	....	....	53 275	35 480	35 510	35 280	27.0	64.8
	No. 2	0.05	C-23	Web...	54 260	32 800	32 800	32 800	26.9	56.6
	No. 1	0.18	C-13		54 060	33 510	33 510	33 510	31.8	65.0
	No. 3	0.44	C-33		54 950	35 650	35 650	35 650	31.2	64.0
	No. 5	0.50	C-53		53 330	34 240	31 960	29 220	36.2	66.9
	No. 4	1.20	C-43		54 400	35 240	35 240	35 240	30.5	64.1
	Mean..	....	....	....	54 200	34 290	33 830	33 280	31.3	63.3
Channel, 15 in., 35 lb.	No. 2	0.05	C-71	Toe....	59 260	38 040	41 000	38 620	18.8	47.5
	No. 2	0.05	C-75		59 670	38 960	39 540	39 540	20.1	51.2
	No. 1	0.18	C-61		59 060	40 320	58 580	40 320	21.5	58.4
	No. 1	0.18	C-65		59 700	40 580	49 610	40 580	20.4	58.9
	No. 3	0.44	C-81		59 560	42 890	42 890	42 890	18.8	53.8
	No. 3	0.44	C-85		62 380	39 650	39 650	39 650	18.8	62.0
	No. 5	0.50	C-101		59 140	41 340	41 340	41 340	29.0	59.8
	No. 5	0.50	C-105		58 140	38 790	38 940	38 940	17.0	59.4
	No. 4	1.20	C-91		60 000	43 260	43 260	43 260	22.8	59.9
	No. 4	1.20	C-95		58 480	44 110	44 110	44 110	19.2	57.6
	Mean..	....	....	....	59 540	40 795	43 890	40 925	20.6	56.9

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[a] See Fig. 1

TABLE VI.—RESULTS OF TENSION TESTS OF SERIES NO. 271 (*Continued*).

Shape	Laboratory	Speed of Head at Yield Point, in. per minute	Specimen Number	Specimen Location[a]	Tensile Strength, lb. per sq. in.	Yield Point, lb. per sq. in.			Elongation in 8 in., per cent	Reduction of Area, per cent
						Drop-of-Beam Method	Scaling Method	Divider Method		
Channel, 15 in., 55 lb.	No. 2	0.05	C-72	Root...	55 640	29 590	......	29 590	32.0	58.0
	No. 2	0.05	C-74		56 000	29 950	......	29 950	31.2	54.0
	No. 1	0.18	C-62		55 130	30 160	32 975	30 160	34.8	63.5
	No. 1	0.18	C-64		55 005	30 690	30 870	30 690	28.4	60.2
	No. 3	0.44	C-82		56 330	31 390	31 390	31 390	29.8	63.0
	No. 3	0.44	C-84		56 460	31 140	31 140	31 140	30.2	58.2
	No. 5	0.50	C-102		55 140	31 030	31 030	31 030	30.0	61.7
	No. 5	0.50	C-104		55 140	31 960	31 960	31 960	34.2	62.8
	No. 4	1.20	C-92		55 860	32 890	32 890	32 890	33.5	61.8
	No. 4	1.20	C-94		55 840	31 440	31 440	31 440	34.7	63.3
	Mean..				55 655	31 025	31 710	31 025	31.9	60.6
	No. 2	0.05	C-73	Web...	56 760	28 610	28 610	28 610	30.0	51.9
	No. 1	0.18	C-63		56 100	29 090	29 090	29 090	33.9	58.6
	No. 3	0.44	C-83		56 630	31 470	31 470	31 470	29.8	57.0
	No. 5	0.50	C-103		55 960	30 190	30 190	30 190	34.0	59.0
	No. 4	1.20	C-93		57 520	30 380	30 380	30 380	35.2	58.1
	Mean..				56 590	29 950	29 950	29 950	32.6	56.9
I-Beam, 24 in., 79.9 lb.	No. 2	0.05	I-21	Toe....	56 440	31 740	31 740	32 140	29.0	58.3
	No. 2	0.05	I-23		56 270	32 000	32 580	32 580	29.4	61.7
	No. 2	0.05	I-27		56 200	31 260	31 530	31 460	27.2	56.1
	No. 2	0.05	I-29		56 110	30 700	31 060	31 060	30.6	55.7
	No. 1	0.18	I-11		56 990	34 700	34 700	34 700	26.6	61.3
	No. 1	0.18	I-13		56 180	33 905	33 905	33 905	25.8	61.9
	No. 1	0.18	I-17		56 100	31 980	31 120	31 980	23.4	57.2
	No. 1	0.18	I-19		56 520	32 530	35 335	32 530	27.1	60.7
	No. 3	0.44	I-31		56 640	34 960	34 960	34 960	28.2	59.2
	No. 3	0.44	I-33		56 670	34 000	34 000	34 000	26.0	60.4
	No. 3	0.44	I-37		56 980	33 280	33 280	33 280	29.0	60.0
	No. 3	0.44	I-39		55 600	33 050	33 050	33 050	28.5	60.3
	No. 5	0.50	I-51		56 170	38 750	37 430	37 430	27.5	63.8
	No. 5	0.50	I-53		55 440	28 715	32 650	33 240	29.2	62.8
	No. 5	0.50	I-57		55 870	30 550	30 550	31 760	29.2	60.4
	No. 5	0.50	I-59		55 620	31 800	33 190	32 320	28.8	57.9
	No. 4	1.20	I-41		56 400	34 560	34 560	34 560	26.5	61.3
	No. 4	1.20	I-43		56 510	35 390	35 390	35 390	29.8	59.1
	No. 4	1.20	I-47		56 670	33 660	33 660	33 660	28.0	58.0
	No. 4	1.20	I-49		55 430	33 440	33 440	33 440	27.8	59.1
	Mean..				56 235	33 050	33 405	33 370	27.9	59.8
	No. 2	0.05	I-22	Flange.	56 800	28 230	......	28 600	28.4	57.7
	No. 2	0.05	I-28		56 870	30 090	......	30 110	30.2	53.5
	No. 1	0.18	I-12		56 830	27 280	......	30 390	31.0	58.9
	No. 1	0.18	I-18		56 640	29 270	......	30 160	29.1	57.5
	No. 3	0.44	I-32		56 690	33 830	33 830	33 830	29.2	63.8
	No. 3	0.44	I-38		57 880	31 690	31 690	31 690	30.8	56.1
	No. 5	0.50	I-52		56 240	29 180	29 180	29 180	31.2	56.5
	No. 5	0.50	I-58		56 480	29 480	36 180	29 480	28.0	60.3
	No. 4	1.20	I-42		56 900	31 340	31 340	31 340	32.5	59.6
	No. 4	1.20	I-48		56 760	32 540	32 540	32 540	31.2	57.5
	Mean..				56 810	30 295	32 460	30 730	30.2	58.1
I-Beam, 24 in., 79 lb.	No. 2	0.05	I-24	Root...	64 400	49 340	54 680	49 400	14.4	53.0
	No. 2	0.05	I-26		62 760	43 470	48 550	44 500	22.2	54.9
	No. 1	0.18	I-14		63 930	......	52 800	50 160	16.6	59.7
	No. 1	0.18	I-16		61 920	42 840	49 430	44 440	19.2	62.4
	No. 3	0.44	I-34		65 140	48 550	48 550	48 550	20.2	56.4
	No. 3	0.44	I-36		62 500	44 670	44 670	44 670	11.2	60.4
	No. 5	0.50	I-54		63 880	48 870	53 880	48 870	......	56.4
	No. 5	0.50	I-56		61 500	43 140	43 140	43 140	20.0	59.2
	No. 4	1.20	I-44		67 130	51 940	51 940	51 940	14.0	56.0
	No. 4	1.20	I-46		61 750	45 090	45 090	45 090	21.0	55.5
	Mean..				63 490	46 435	49 275	47 075	17.6	56.2
	No. 2	0.05	I-25	Web...	59 270	32 200	32 200	32 200	30.2	53.7
	No. 1	0.18	I-15		58 890	31 540	31 540	32 350	27.0	54.4
	No. 3	0.44	I-35		59 750	36 200	36 200	36 200	33.5	57.1
	No. 5	0.50	I-55		58 200	34 640	34 640	34 640	31.2	60.4
	No. 4	1.20	I-45		59 770	35 250	35 250	35 250	31.8	59.6
	Mean..				59 175	33 900	33 965	34 130	30.7	57.0

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[a] See Fig. 1.

TABLE VI.—RESULTS OF TENSION TESTS OF SERIES NO. 271 (*Continued*).

Shape	Laboratory	Speed of Head at Yield Point, in. per minute	Specimen Number	Specimen Location[a]	Tensile Strength, lb. per sq. in.	Yield Point, lb. per sq. in.			Elongation in 8 in., per cent	Reduction of Area, per cent
						Drop-of-Beam Method	Scaling Method	Divider Method		
I-Beam, 24 in., 100 lb.	No. 2	0.05	I-71	Toe....	58 200	31 520	......	33 350	23.8	54.4
	No. 2	0.05	I-73		58 680	32 180	33 650	33 650	26.0	55.3
	No. 2	0.05	I-77		58 700	31 770	......	31 770	28.1	56.6
	No. 2	0.05	I-79		71 590	35 520	35 800	35 520	25.0	40.2
	No. 1	0.18	I-61		58 230	32 120	43 770	32 670	23.0	55.6
	No. 1	0.18	I-63		58 790	33 305	36 660	33 305	26.4	56.8
	No. 1	0.18	I-67		59 005	36 350	41 955	36 350	29.5	57.1
	No. 1	0.18	I-69		59 590	35 800	45 760	36 200	25.8	51.5
	No. 3	0.44	I-81		59 900	37 630	37 630	37 630	26.5	58.2
	No. 3	0.44	I-83		60 230	37 990	37 990	37 990	30.0	57.5
	No. 3	0.44	I-87		59 690	34 650	34 650	34 650	......	58.2
	No. 3	0.44	I-89		59 500	33 910	33 910	33 910	28.0	59.2
	No. 5	0.50	I-101		57 920	30 630	34 420	33 790	25.5	56.6
	No. 5	0.50	I-103		58 880	33 520	34 080	34 080	25.8	58.4
	No. 5	0.50	I-107		58 720	37 170	37 170	37 170	27.5	58.6
	No. 5	0.50	I-109		59 360	36 380	37 540	37 540	25.8	59.1
	No. 4	1.20	I-91		58 820	36 040	36 040	36 040	27.5	56.9
	No. 4	1.20	I-93		58 270	36 740	36 740	36 740	27.5	56.0
	No. 4	1.20	I-97		60 730	37 380	37 380	37 380	28.0	58.8
	No. 4	1.20	I-99		59 430	37 860	37 860	37 860	26.0	57.2
	Mean..	....	....	....	59 712	34 925	37 390	35 380	26.6	56.1
	No. 2	0.05	I-72	Flange.	57 300	27 360	......	28 140	33.8	56.7
	No. 2	0.05	I-78		56 670	26 690	......	27 060	33.1	58.0
	No. 1	0.18	I-62		57 210	27 970	......	27 970	32.4	56.8
	No. 1	0.18	I-68		57 280	28 335	......	28 335	33.8	58.3
	No. 3	0.44	I-82		57 970	29 510	29 510	29 510	36.0	55.2
	No. 3	0.44	I-88		58 630	28 850	28 850	28 850	33.5	58.3
	No. 5	0.50	I-102		56 980	28 640	36 480	28 640	32.2	58.2
	No. 5	0.50	I-108		56 700	28 430	34 960	28 430	32.2	59.2
	No. 4	1.20	I-92		57 930	30 260	30 260	30 260	33.5	57.6
	No. 4	1.20	I-98		57 320	30 760	30 760	30 760	35.2	58.3
	Mean..	....	....	....	57 400	28 680	31 805	28 795	33.6	57.7
I-Beam, 24 in., 100 lb.	No. 2	0.05	I-74	Root...	64 260	48 260	58 850	47 830	18.1	52.4
	No. 2	0.05	I-76		66 720	54 750	......	54 440	14.8	50.9
	No. 1	0.18	I-64		64 070	......	46 900	43 920	18.5	57.0
	No. 1	0.18	I-66		66 380	54 160	61 990	53 020	16.4	54.9
	No. 3	0.44	I-84		68 940	55 470	55 470	55 470	28.5	54.3
	No. 3	0.44	I-86		64 430	47 140	47 140	47 140	......	57.2
	No. 5	0.50	I-104		61 350	42 000	42 920	42 000	30.8	59.1
	No. 5	0.50	I-106		67 400	49 600	56 700	53 950	....	55.0
	No. 4	1.20	I-94		64 140	47 030	47 030	47 030	17.8	55.0
	No. 4	1.20	I-96		67 640	51 310	51 310	51 310	14.2	55.9
	Mean..	....	....	....	65 530	49 970	52 030	49 610	19.9	55.2
	No. 2	0.05	I-75	Web...	59 680	29 110	......	29 670	28.8	48.7
	No. 1	0.18	I-65		59 970	30 420	30 420	30 420	28.9	50.8
	No. 3	0.44	I-85		60 170	31 730	31 730	31 730	27.5	52.2
	No. 5	0.50	I-105		58 280	30 080	56 990	30 080	29.5	52.9
	No. 4	1.20	I-95		58 430	31 210	31 210	31 210	31.2	51.3
	Mean..	....	....	....	59 300	30 510	37 570	30 620	29.2	51.5

[a] See Fig. 1.

between average variation from mean and speed. Considering all specimens, the average variations are approximately the same for the range in speed.

Examination of the elongation and reduction in area percentages in the last two columns of Table VI show that there was also a considerable range in the ductility of the specimens tested in Series No. 271. Specimens from center of heavy plate, from heavy angle, from webs of channels and flanges of I-beams exhibited high elongations whereas specimens from toes of channels and roots of I-beams exhibited low elongations.

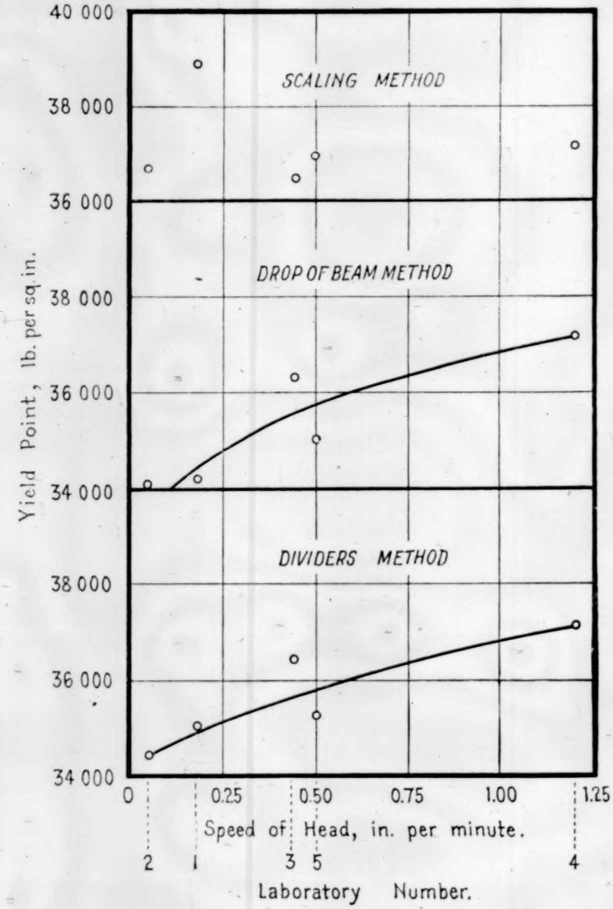

FIG. 8.—Relationship of Average Yield Points of All Specimens Tested at a Given Speed, Series No. 271. Each point represents 40 tests.

The foregoing data indicate that the specimens of this series of tests exceeded the range both in strength and ductility permitted by specifications for structural carbon steel for bridges.

Effect of Speed on Yield Point.—The yield point data in Table V have been plotted in Fig. 8. The figure shows that the yield point determined by scaling did not bear any consistent relation to speed of head. For a change in speed from 0.05 to 1.2 in. per minute the middle curve of Fig. 8 shows that the yield point by drop of beam increased 3200 lb. per sq. in., or 9 per cent, and the lower curve shows that the yield point by dividers increased 2800 lb. per sq. in., or 8 per cent,

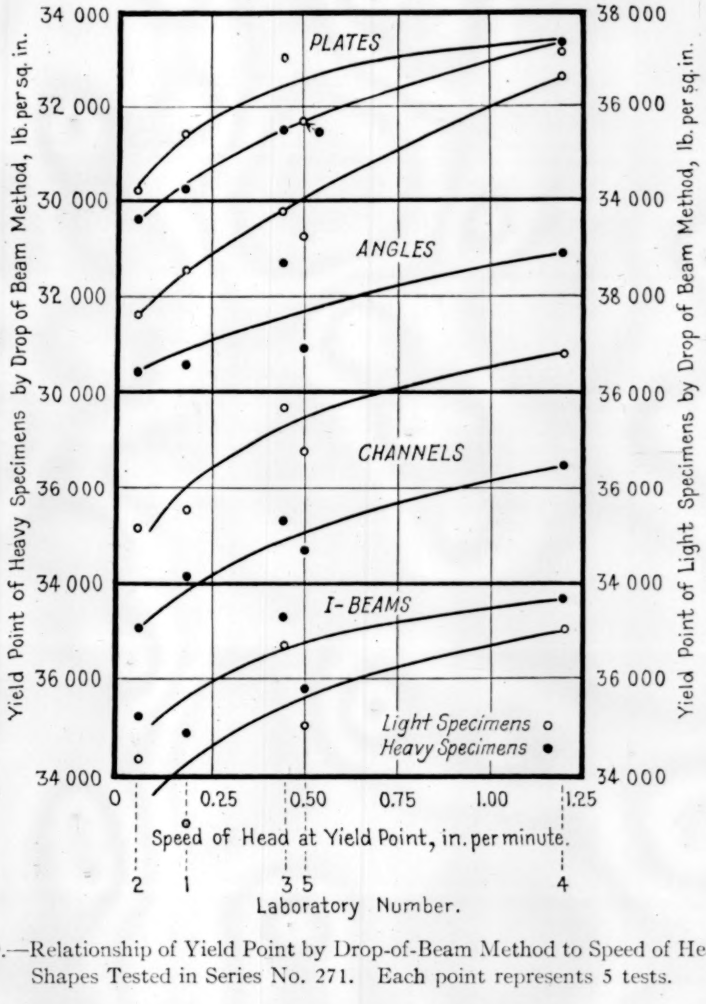

FIG. 9.—Relationship of Yield Point by Drop-of-Beam Method to Speed of Head for Shapes Tested in Series No. 271. Each point represents 5 tests.

for a speed change from 0.05 to 1.2 in. per minute. From the upper curve in Fig. 2 one observes that the increase in yield point by drop of beam for the carbon steels of Series No. 261 corresponding to the same increase in speed was 2700 lb. per sq. in. From Figs. 9 and 10 it will be observed that the yield point - speed curves for the different shapes all show that the indicated yield point was increased by increasing the speed of loading. Bearing in mind the variability of the material, the general agreement in the shape of these curves with the average curves of Fig. 8 and Fig. 2 is significant.

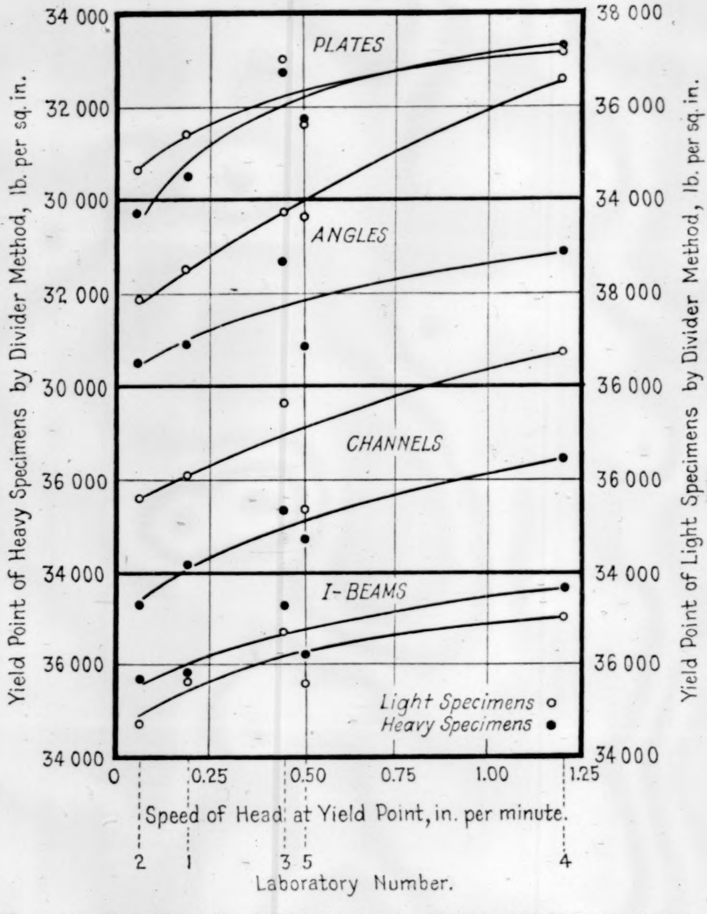

FIG. 10.—Relationship of Yield Point by Divider Method to Speed of Head for Shapes Tested in Series No. 271. Each point represents 5 tests.

In Figs. 11 and 12 are shown average percentage variations from means for the groups of specimens from a given shape tested at each speed. In calculating these data the mean yield point for the specimens from a single shape tested at the same speed was computed.

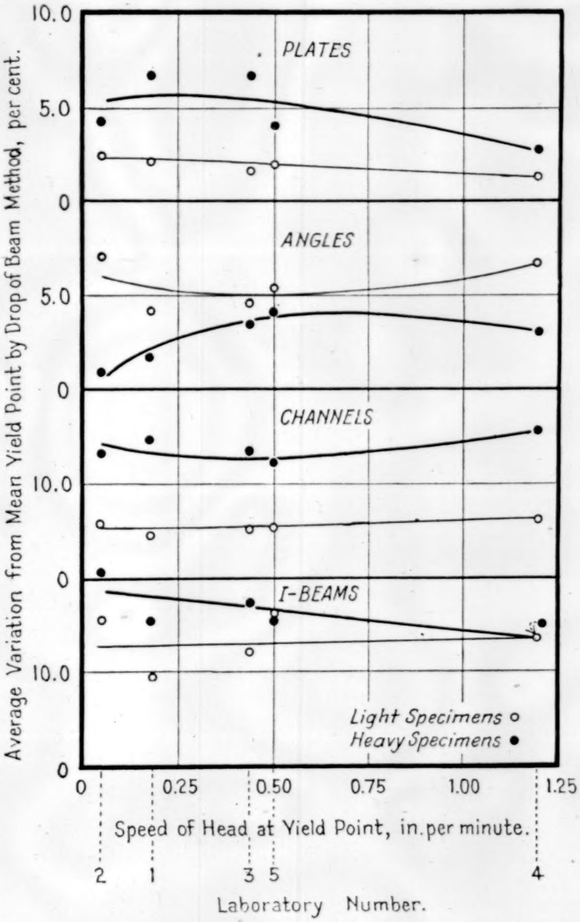

FIG. 11.—Average Percentage Variation from Mean Yield Point by Drop-of-Beam Method, Series No. 271.

Then the average percentage variation for the same group was calculated and plotted against the proper speed. It should be observed that in calculations for Fig. 11 the 3 root specimens exhibiting no yield point by drop of beam, Table VI, were omitted. Whereas there are considerable differences in the shapes of the individual curves in these two figures, taken as a whole the data tend to show that within the speed range covered by the tests the average percentage variation is not materially influenced by speed of loading. Comparison of the curve ordinates for the plate and I-beam specimens plainly shows that the variability of the material itself did influence the average variation markedly.

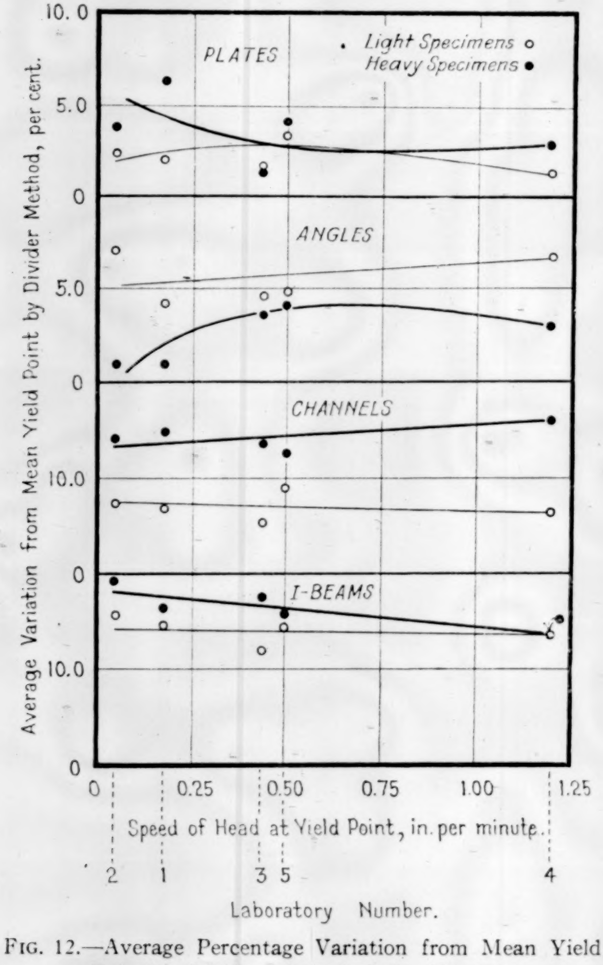

FIG. 12.—Average Percentage Variation from Mean Yield Point by Divider Method, Series No. 271.

Comparison of Methods for Detecting Yield Point.—Considering data of Figs. 11 and 12, the average percentage variation from the mean for all speeds is practically the same for yield point by dividers and for yield point by drop of beam. From the average yield points in Table V it will be noted that the average yield point by drop of beam was the lowest, the average yield point by dividers was approximately 0.8 per cent higher, and the average yield point by scaling was 5.2 per cent higher than by drop of beam. In this connection it should again be noted from Table VI that at Wisconsin *no drop of beam indication* was observed on three of the root specimens, and that *no indications of yield point* by scaling were recorded for 21 of the specimens tested at Rensselaer and at Wisconsin. *In all tests there was positive indication of the yield point given by the dividers.* Hence, the divider indication was the most reliable of the three methods. The scaling indication was very unreliable for specimens with scale on one side only. and in general less certain than either of the other two methods.

Effect of Speed at Yield Point on Time of Testing.—In Table V the speeds used by the different laboratories and some data on the average time per test are given. From these data no consistent relation between speed at yield point and average time from zero load to failure, or average total time for test, appears. Since the time required to test a specimen at a given speed is determined by the amount the specimen will stretch before rupture, and since the stretch of structural steel up to yield point is only about 0.25 to 0.5 per cent, whereas the total stretch is 20 to 30 per cent, it follows that the time required to determine the yield point is between one and two per cent of the total time to rupture. Hence, with specimens having gage lengths of eight diameters or more, half of the stretching up to yield point can be done at a speed only one-tenth as fast as the initial or final speed without materially increasing the total time for the test.

Effect of Location of Specimen on Yield Point.—The data on mean strength, yield point, and ductility, Table VI, show that there is a considerable variation in these properties for specimens taken from different parts of angles, channels, and I-beams.

For the plates the drop of beam yield points of the edge specimens averaged three per cent higher than the mean yield point of the center specimens for the $\frac{3}{8}$-in. plate, and 12 per cent higher for the $\frac{7}{8}$-in. plate.

The mean drop of beam yield point for toe specimens of $\frac{3}{8}$-in. angles was 12 per cent lower than the mean yield point for the root specimens. For the $\frac{7}{8}$-in. angles the mean divider yield point of the toe specimens was five per cent higher than the mean yield point of the root specimens.

Considering the 35-lb. channel, the mean yield point by drop of beam for the toe specimens was 15 per cent, and for the root specimens 4 per cent, higher than the corresponding mean yield point for the web specimens. The mean yield points by drop of beam for the toe and root specimens of the 55-lb. channel were 36 and 4 per cent, respectively, higher than the mean yield point of the web specimens.

For the 79.9-lb. I-beam, the mean divider yield points for the toe and mid-flange specimens were, respectively, 2 and 10 per cent less than the mean yield point of web specimens, whereas the mean divider yield point of the root specimens was 38 per cent higher than that of the web specimens. The mean divider yield points of the toe and root specimens from the 100-lb. I-beam were, respectively, 16 and 62 per cent higher than the mean yield point of the corresponding web specimens, whereas the mean yield point of the mid-flange specimens was 6 per cent lower than that of the web specimens.

TABLE VII.—COMPARISON OF YIELD POINTS OF LIGHT AND HEAVY SHAPES OF SERIES NO. 271.

		Shape			
		Plate	Angle	Channel	I-Beam
Specimens Location[a]		Edge	Toe	Web	Web
Yield Point, lb. per sq. in.	Heavy Shape	32 425	31 955	29 950	30 510
	Light Shape	36 270	37 900	34 290	33 900
Excess Light Shape Over Heavy Shape, per cent		12	19	15	11

[a] See Fig. 1.

Comparisons of Yield Points of Light and Heavy Shapes.—The chemical compositions, Table I, of the metal in the specimens from the different shapes were fairly uniform, though there were differences in the carbon and manganese contents of the light and heavy sections of plates and channels which would tend to make the strength of the heavy sections greater, whereas the composition differences in the angles would tend to make the strength of light angles greater.

The comparison in Table VII furnishes quantitative data on the difference in yield points of the light and heavy shapes.

CONCLUSIONS

For the machines and materials used in these tests, the conclusions which follow are drawn. Since the tensile specimens had a free length of approximately 10 in. between grips, rate of strain per inch of length was not over one-tenth of the speed.

1. Increasing the speed of loading from 0.05 to 2.0 in. per minute caused the following average increases in the yield point in tension of the bar steels tested:

Carbon steel	3900 lb. per sq. in., or 9 per cent
Nickel steel	4800 lb. per sq. in., or 7 per cent
Silicon steel	6500 lb. per sq. in., or 12 per cent

2. At a speed of 0.2 in. per minute the yield point by drop of beam was 600 to 1000 lb. per sq. in. higher than at a speed of 0.05 in. per minute.

3. For the uniform bar structural steels the maximum range in yield point by drop of beam of the five laboratory averages of five tests each was:

Carbon steel at $\frac{1}{8}$ in. per minute	1600 lb. per sq. in., or 4 per cent
Carbon steel at $\frac{1}{2}$ in. per minute	1850 lb. per sq. in., or 5 per cent
Nickel steel at $\frac{1}{8}$ in. per minute	2000 lb. per sq. in., or 3 per cent
Nickel steel at $\frac{1}{2}$ in. per minute	1600 lb. per sq. in., or 2 per cent
Silicon steel at $\frac{1}{8}$ in. per minute	2700 lb. per sq. in., or 5 per cent
Silicon steel at $\frac{1}{2}$ in. per minute	2800 lb. per sq. in., or 5 per cent

The maximum range in the 25 individual test values at these speeds was approximately double the values given above.

4. The maximum range in drop of beam yield points considering averages of five specimens, all speeds, and laboratories included, was 10 per cent for carbon steel, 6 per cent for nickel steel, and 11 per cent for the silicon steel.

5. Of the four methods used in detecting the yield point the multiplying divider method was the most reliable and gave values slightly less variable than the drop of beam method. The 2-in. strain gage did not prove quite so satisfactory in detecting yield point as the 8-in. dividers. Scaling was not so satisfactory an index of yield point in the carbon or silicon bar steels as the other methods. For the nickel bar steel and for specimens cut from shapes with scale on one surface only, scaling proved an unreliable index of yield point. The drop of beam method was the simplest and quickest, and in most cases sufficiently reliable.

6. Yield points by drop of beam averaged the same as yield points by dividers in Series No. 261. In Series No. 271 yield points by drop of beam averaged 0.8 per cent lower than the yield points by dividers. Part of the latter discrepancy was undoubtedly due to the large value of strain (0.5 per cent) adopted in these tests as the divider index of yield point.

7. In determining yield points by drop of beam, especially at speeds of 0.5 in. per minute or less, care must be taken to avoid false

indications of yield point arising from the momentary drop of beam due to overstrain at the grips.

8. The average ratio of the yield point in tension to yield point in compression was 0.97 for each of the steels tested in Series No. 261.

9. For the more variable rectangular specimens cut from structural shapes of carbon steel (Series No. 271), the effect of speed on yield point was somewhat greater than for the uniform bar steels of Series No. 261.

10. Variation of individual yield points from mean values was much greater in the tests of Series No. 271 than with the uniform steels of Series No. 261. In both series of tests the variations were not materially influenced by speed of testing.

11. There were marked differences in the yield points of specimens cut from various portions of structural steel shapes. These differences were least in the specimens cut from plates and greatest in the specimens from I-beams. Specimens from toes of channels and roots of I-beams exhibited yield points much higher than the yield points of the corresponding web specimens.

12. The yield point of specimens from the light shapes, $\frac{3}{8}$ in. thick, were 11 to 19 per cent higher than the yield points of specimens from the heavy shapes, $\frac{7}{8}$ in. thick.

13. Reducing momentarily the speed in the vicinity of the yield point to 0.2 in. per minute had little effect on the total time per test.

Acknowledgments.—The committee gratefully acknowledges the effective cooperation of Mr. F. S. Crane of the Illinois Steel Co. who supervised the selection and preparation of the test specimens. Credit for the care taken in performing the tests is due the assistants in the five participating laboratories.

Respectfully submitted on behalf of the committee,

M. O. WITHEY,
Chairman.

DISCUSSION

Mr. Tuckerman.

MR. L. B. TUCKERMAN.[1]—I want to take occasion to congratulate the committee on carrying out a very tedious and time-consuming job, and doing it so well. The Bureau of Standards some time ago became interested in the question of the speed of testing and made a few very inconclusive experiments upon the speed of testing machines, and two or three points come to mind which might be brought out that were not brought out in the presentation of the report. In our experiments we found that the differences were not merely machine differences and laboratory differences, but also individual differences, and I think that a study of the series in detail will show that the average change of yield point with speed of testing was sufficiently different in the different laboratories to indicate that there were in these tests also the differences between the individuals who were taking the readings. The most important part of the report is of course that the consistency of yield point determination is practically independent of the machine and the speed of testing. If, however, one is using a certain machine and a certain speed of testing and one wants to compare the yield point with that determined by another machine at another speed of testing (or, to a slight extent, by another individual) one must have a knowledge of the difference between the results from the different machines and different speeds.

In studying those curves, one will notice that the consistency of the results improves as the speed of testing decreases; that is, the difference between different testing machines and different individuals (with the exception of one particular curve) decreases as the speed of testing is decreased. The slowest speeds used at the Bureau of Standards were just about one-fifth or one-fourth of the slowest speed used by the committee, and it seemed to us that the differences between the approximately 0.05 in. per minute and 0.01 in. per minute were quite significant and that even more consistent results would be obtained by a slower speed of testing; so that if comparisons of yield point determination upon materials which do show definite yield point are made between different laboratories, it would seem desirable that the comparison be based upon a series of check tests run with the same machine, and, if individual variations are sufficiently great, with the individual observer, to see that he does not show an excessive personal error at speeds approximately 0.01 in. per minute. If under those circumstances different observers and

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[1] Engineer Physicist, U. S. Bureau of Standards, Chevy Chase, Md.

Mr. Tuckerman. different machines should yield consistent results, then a comparison of higher speed testing with these results in each laboratory will enable inter-comparison of results taken under different conditions with different laboratories, without the necessity of direct comparison at the higher speeds.

Mr. Smith. MR. H. E. SMITH.[1]—I have found one point in testing to which I should like to call attention, and that is the possibility at high speed of over-running a true balancing of the beam. In this committee work probably nothing of that kind occurred, and the arrangements were such that the beam was kept properly floating all the time, but in rapid commercial testing at high speeds there is often an unduly high figure obtained simply because although the machine would indicate the yield point correctly when the beam is floating, it is difficult to keep it floating and there is great opportunity for over-running the true load.

Mr. Burgess. MR. G. K. BURGESS.[2]—I should like also to congratulate the committee on its very excellent report. Also I should like to ask two questions: one is whether the committee feels it can recommend a standard practice as to speed on the one hand, bearing in mind cost and time consumed, and whether it would recommend a preferred method among those used? I think a selection of a standard speed and standard method might be very helpful in the light of the experience of the committee.

Mr. Menefee. MR. F. N. MENEFEE.[3]—There are two questions I should like to ask. How are the specimens gripped, and was there any data taken in respect to the modulus of elasticity? It looks a little as if the value of modulus of elasticity might have been increased in these tests, and to me that would be something of considerable interest. I can remember during the World War some of us became quite concerned over what we felt was the high calculated stress in shells and guns. Our calculations we thought were right, but in some cases they ran higher than the acceptable stresses for the elastic limit. The conclusion we finally reached was that the material did not have time to deform, and therefore the ordinary elastic limit was exceeded without undue distortion or permanent set. The idea seems to be supported by these tests. In other words, one may go considerably beyond the static elastic limit and still do no harm in the case of a swiftly applied load. That is the reason for the question as to whether any tests had been made to determine values of modulus of elasticity. If such data could be supplied they would be very valuable.

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[1] Engineer of Materials, New York Central Lines, New York City.

[2] Director, U. S. Bureau of Standards, Washington, D. C.

[3] Professor of Engineering Mechanics, University of Michigan, Ann Arbor, Mich.

Mr. Lawson.

MR. T. R. LAWSON.[1]—Speaking for one of the laboratories that participated in this series of tests, I desire to say in answer to a question that has been asked that but little attention was given to the determination of the value of modulus of elasticity at the high speeds. The load was continuously applied and the difficulty of correctly reading the scale beam under a given stretch of the specimen below the yield point and under a speed of $1\frac{1}{2}$ in. per minute was such as to render the results unreliable. At lower speeds, however, some modulus of elasticity determinations were made, and the value was found to be sensibly constant. With reference to the method of gripping, all of the specimens were gripped in the same manner: that is, in the ordinary serrated grips of the testing machine.

In discussion of one of the papers presented at this annual meeting[2] mention was made of the appearance of Lüders lines on test specimens; also the false determination of yield point due to the local stresses that are induced by the compression due to the grips. These Lüders lines were quite prominent on many of the specimens tested in this series. They invariably appeared first at the top of the specimen at the point where it entered the serrated grips and rapidly traveled down to about one quarter of the length of the specimen. They then began at the bottom of the specimen and traveled upward until the series met near the center.

As soon as the Lüders lines appeared just below the grips there was a momentary drop of the scale beam, which indicated that the yield point of some part of the specimen had been reached. The definite drop of the beam occurred when the lines had come well within the limits of the 8-in. gage marks on the specimen.

It is a matter of common knowledge that the specimens of iron and steel become magnetic when tested in tension. We found that, in addition to this, the upper end of the specimen invariably became the north pole. If load beyond the yield point was applied and the specimen taken from the vertical machine and reversed end for end, the polarity of the specimen would also change upon the reapplication of load, the upper end becoming the north pole as before.

Mr. Withey.

MR. M. O. WITHEY[3] (*Chairman of the Research Committee*).—In reply to the questions raised by Mr. Burgess, the committee did not consider that its function was that of formulating specifications. It was thought that Committee E-1 on Methods of Testing can make use, as it deems fit, of the data here presented.

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[1] Head, Department of Civil Engineering, Rensselaer Polytechnic Institute, Troy, N. Y.

[2] Discussion of paper by J. M. Lessells "Concerning the Yield Point in Tension," *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part II, p. 393 (1928).

[3] Professor of Mechanics, University of Wisconsin, Madison, Wis.

REPORT OF COMMITTEE A-2

ON

WROUGHT IRON

During the past year the committee held one meeting, March 21, 1928. A second meeting will be held prior to the presentation of this report to the Society at which the report will be reviewed and other matters considered.

The present membership of the committee is 59, of which 28 are classed as producers, 26 as consumers and 5 as general interests.

RECOMMENDATIONS AFFECTING STANDARDS AND TENTATIVE STANDARDS

I. Proposed Revisions in Standards:

The committee recommends that the following revisions of the Standard Specifications for Staybolt, Engine-Bolt and Extra-Refined Wrought-Iron Bars (A 84 - 27) be accepted for publication as tentative:

Section 7. (a).—Change to read as follows by the addition of the italicized words and the omission of those in brackets:

> (*a*) Grade A.—For bars $\frac{7}{8}$ in. [or under] in diameter, a reduction in the minimum elongation in 8 in. specified in Section 6 (*a*) shall be permitted, but in no case shall the elongation be less than 28 per cent. *For bars $\frac{3}{4}$ in. or under in diameter, the elongation shall not be less than 25 per cent*

II. Proposed New Tentative Standards:

The committee recommends that the proposed new Tentative Specifications for Iron and Steel Chain, appended hereto,[1] be accepted for publication as tentative to supersede, when adopted, the present Standard Specifications for Iron and Steel Chain (A 56 - 24). The proposed specifications cover steel as well as wrought-iron chain and have therefore been submitted to Committee A-1 on Steel for its approval on the requirements for steel chain.

The above recommendations have been referred to letter ballot of the committee, which consists of 59 members; 43 ballots have been cast, 16 members did not return their ballots. The analysis of the vote of the committee is given in the following table:

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[1] See p. 697.—ED.

Items	Affirmative	Negative	Not Voting[a]
I. PROPOSED REVISIONS IN STANDARDS			
A 84 - 27 Specifications for Staybolt, Engine-Bolt and Extra-Refined Wrought-Iron Bars	41	0	2
II. PROPOSED NEW TENTATIVE STANDARDS			
Tentative Specifications for Iron and Steel Chain	35	1	7

[a] In this column are recorded the number of votes cast as "Not Voting" on the various items.

Total number of ballots cast	43
Number of members who failed to vote	16
Total Membership	59

Sub-Committee III on Staybolt and Engine-Bolt Iron (E. J. Edwards, chairman).—This sub-committee is recommending a revision in the Standard Specification for Staybolt, Engine-Bolt and Extra-Refined Wrought-Iron Bars (A 84 - 27) which consists of a reduction in the required percentage of elongation for staybolt iron, sizes $\frac{3}{4}$ in. in diameter and under. This revision is recommended by consumers who have found difficulty in obtaining staybolt iron of these small sizes having the specified elongation.

The sub-committee has under consideration the inclusion of a vibratory test requirement for staybolt iron in the above specifications and revisions in the Standard Specifications for Hollow Rolled Staybolt Iron (A 86 - 27).

Sub-Committee V on Chain Iron and Iron Chain (F. M. Waring, chairman).—This sub-committee is presenting a complete revision of the existing Standard Specification for Iron and Steel Chain (A 56 - 24) in the form of proposed new tentative specifications[1] which are intended eventually to replace the existing standard specification.

Sub-Committee VI on Wrought-Iron Blooms and Forgings (H. E. Smith, chairman).—This sub-committee is gathering data preparatory to investigating the possible difference in physical properties of wrought iron, forged under a hammer or press and wrought iron rolled.

Sub-Committee VIII on Methods of Physical Testing.—At the request of its chairman, Mr. F. M. Waring, this sub-committee has been discontinued. The present organization of Committee E-1 on Methods of Testing, on which Committee A-2 is represented, relieves Sub-Committee VIII of its former activities and its continuation would lead only to a duplication of effort.

Sub-Committee X on Research (H. W. Faus, chairman).—The sub-committee is engaged in an exhaustive study of what constitutes quality in wrought iron. A sub-sub-committee has been appointed to prepare a preliminary report which will then be reviewed by Sub-Committee X. The final report should prove of great interest and value to the wrought iron industry in general.

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[1] See p. 697.—ED.

The sub-committee is also investigating through a sub-sub-committee, the effect of phosphorus in varying amounts on staybolt iron. Several groups of samples have been furnished in which the method of manufacture and the chemical composition, with the exception of the phosphorus, are as nearly as possible identical. The samples will be analyzed and tested physically in the annealed and unannealed state.

Committee A-2 has appointed a sub-committee consisting of the chairmen of all other sub-committees of Committee A-2 to consider the revision of the process clauses in the various specifications for wrought iron products so as to insure highest quality material without restricting the manufacture of the material to any one process.

The present officers of the committee have been re-elected for the ensuing two years.

This report has been submitted to letter ballot of the committee, which consists of 59 members; 44 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

H. W. FAUS,
Chairman.

G. H. WOODROFFE,
Secretary.

EDITORIAL NOTE

The proposed revision of the Standard Specifications for Staybolt, Engine-Bolt and Extra-Refined Wrought-Iron Bars was accepted for publication as tentative and appears on page 1115.

The proposed Specifications for Iron and Steel Chain were accepted for publication as tentative, to supersede, when adopted, the present standard specifications. The tentative specifications appear on page 697.

REPORT OF COMMITTEE A-3
ON
CAST IRON

Since the 1927 annual meeting of the Society, Committe A-3 has held two meetings, one an informal meeting on September 21, 1927, during the convention of the American Society for Steel Treating at Detroit, and the other at Washington on March 22, 1928. The third meeting will be held prior to the presentation of this report to the Society, at which time the report will be reviewed and other matters considered. The present membership of the committee is 75, of which 47 are classified as non-producers and 28 as producers.

The committee adopted resolutions in memory of the late H. V. Wille and the late Gaetano Lanza, who were members of Committee A-3 for many years and who died during the past year.

RECOMMENDATIONS AFFECTING STANDARDS

In 1927, Committee A-3 recommended revisions in the following standards:[1]

Specifications for Gray-Iron Castings (A 48 – 18);
Specifications for Cast-Iron Soil Pipe and Fittings (A 74 – 18);
Specifications for High-Test Gray-Iron Castings (A 88 – 24).

These revisions consisted in a change in the arbitration test bar used for the transverse test and a change in the test bar used in the tension test for cast iron, as affecting these three specifications.

The committee now recommends the removal of the description of the test bars from these three specifications and the setting up of a separate standard describing the transverse test bar and the tension test bar. This separate description is appended to this report. With this change, which is a change in form and not in substance, the committee recommends that the above revisions in specifications remain tentative for another year.

Changes in Test Bars.—The arbitration test bar for the transverse testing of cast iron has received further consideration during the past year. A number of the members of the committee have felt that one size of test bar will not give results which are representative of the various sections used in gray-iron castings. Consequently, it was urged that the committee set up three distinct sizes of test bars to represent light, medium and heavy-section castings. After due consideration, the committee decided to retain the one size of test bar for the present.[1] It was pointed out that the test bar represented the metal in the ladle and not the metal in the casting.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, pp. 1089–1091 (1927); also 1927 Book of A.S.T.M. Tentative Standards, pp. 763–765.

SUB-COMMITTEE ACTIVITIES

Sub-Committee III on Cylinders has been active in making comparative tests on the 1.25-in. diameter test bar as against the 1.20-in. test bar to be applied for use in testing locomotive cylinders.

Sub-Committee VIII on Cast-Iron Soil Pipe and Fittings has prepared proposed tentative specifications for cast-iron culvert pipe, which have been submitted to the members of the sub-committee for criticism. These specifications will be submitted to the Society within the coming year.

Sub-Committee XIII on High-Test Cast-Iron has been working on the revision of the Standard Specifications for High-Test Gray-Iron Castings (A 88 - 24). The sub-committee has suggested a revision increasing the physical properties on high-strength cast iron.

Sub-Committee XIV on Correlation of Test Bar and Castings has carried out a number of tests, the results of which are given in the Appendix to this report.

Sub-Committee XVI on the Heat Treatment of Cast Iron has been organized during the past year and is now engaged in securing information as to heat treating practices on cast iron employed in this country. A questionnaire has been sent out.

Fatigue Tests.—Committee A-3 has sponsored investigations on the fatigue values of cast iron. A number of the members of Committee A-3 have supplied funds and test bars and the work has been performed by J. B. Kommers of the University of Wisconsin. The results of this work are published in a paper presented before the Society at this annual meeting.[2]

Due to ill health, Mr. R. S. MacPherran found it necessary to give up the duties as chairman. New officers were elected to serve for the ensuing two years as follows: Hyman Bornstein, chairman; E. J. Lowry, vice-chairman; and F. B. Coyle, secretary.

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[1] See p. 738.—ED.

[2] J. B. Kommers, "The Static and Fatigue Properties of Some Cast Irons," *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part II, p. 174 (1928).

This report has been submitted to letter ballot of the committee, which consists of 75 members; 30 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

R. S. MacPherran,
Chairman.

H. Bornstein,
Secretary.

EDITORIAL NOTE

A revision of the test bars used for testing cast iron in the form of separate proposed specifications for the Arbitration Test Bar and Tension Test Specimen for Cast Iron was accepted for publication as tentative and appears on page 738. The acceptance of this revision as a separate tentative specification affected tentative revisions which were accepted in 1927 of three Standard Specifications, namely, for Gray Iron Castings; for Cast-Iron Soil Pipe and Fittings and for High-Test Gray Iron Castings. The tentative revisions of the three standard specifications have accordingly been editorially changed and appear on pages 1115, 1116 and 1117, respectively.

APPENDIX

REPORT ON CORRELATION TENSION AND TRANSVERSE TESTS OF CAST IRON

A number of tests were made at the Cleveland foundry of the Westinghouse Electric and Manufacturing Co. to determine the correlation of standard A.S.T.M. arbitration bars of varying diameters.

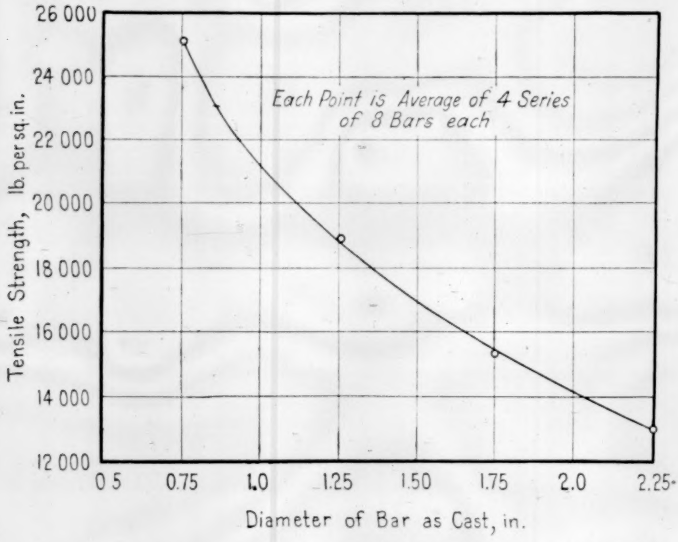

FIG. 1.—Curve Showing Relation Between Tensile Strength of Test Bars Cast of Various Diameters, from the Same Iron, and Machined to 0.505 in. in Diameter.

Four series of tests were made, varying in chemical composition, each series or set of bars being cast from one ladle of cupola melted iron. The chemical analysis of the four series as determined on broken transverse test bars was as follows:

Series	Material	Chemical Analysis, per cent						
		Combined Carbon	Graphitic Carbon	Total Carbon	Manganese	Phosphorus	Sulfur	Silicon
No. 1	Lamp Post Iron	0.57	3.11	3.68	0.65	0.367	0.080	2.15
No. 2	Lamp Post Iron	0.46	3.08	3.54	0.68	0.360	0.076	2.10
No. 3	Motor Bracket Iron	0.60	3.05	3.65	0.66	0.381	0.072	2.12
No. 4	Grid Iron	0.45	3.02	3.47	0.70	0.367	0.092	2.49

In each series, eight bars were cast in four diameters, two bars 0.750 in. in diameter, two bars 1.250 in. in diameter, two bars 1.750 in. in diameter and two bars 2.250 in. in diameter. All transverse tests were made using a distance of 12 in. between supports. The tension tests were made on tension test specimens 0.505 in. in diameter machined from broken halves of the transverse test bars. The results of the transverse tests and of the tension tests are given in Table I. The results of the tension tests showing the relation between tensile strength and diameter of bar as cast are also shown in Fig. 1.

TABLE I.—RESULTS OF TRANSVERSE AND TENSION TESTS ON CAST-IRON BARS OF VARIOUS DIAMETERS.

Series	Material	Bar	Diameter of Bar, in.[a]	Transverse Test			Tensile Strength, lb. per sq. in.
				Load, lb.	Modulus of Rupture, lb. per sq. in.	Deflection, in.	
No. 1 ...	Lamp Post Iron.......	No. 1....	2.250	15 010	40 300	0.097	11 500
		No. 2....	2.250	14 600	39 100	0.093	12 500
		No. 3....	1.750	8 880	50 100	0.095	14 875
		No. 4....	1.750	6 645	37 800	0.060	14 875
		No. 5....	1.250	3 785	59 200	0.127	19 500
		No. 6....	1.250	3 690	57 800	0.105	18 125
		No. 7....	0.750	1 530	110 900	0.122	24 500
		No. 8....	0.750	1 335	96 800	0.127	26 625
No. 2 ...	Lamp Post Iron......	No. 1....	2.250	13 910	37 200	0.076	11 500
		No. 2....	2.250	14 130	38 000	0.079	14 250
		No. 3....	1.750	8 640	49 400	0.087	14 625
		No. 4....	1.750	8 955	51 250	0.106	18 875
		No. 5....	1.250	3 755	58 900	0.121	19 125
		No. 6....	1.250	3 695	58 000	0.102	26 250
		No. 7....	0.750	1 520	113 500	0.157	25 375
		No. 8....	0.750	1 535	109 300	0.148	......
No. 3 ...	Motor Bracket Ingot..	No. 1....	2.750	14 375	38 600	0.084	13 500
		No. 2....	2.250	13 220	35 500	0.078	15 000
		No. 3....	1.750	6 000	43 700	0.079	17 250
		No. 4....	1.750	7 620	43 400	0.079	16 750
		No. 5....	1.250	3 410	53 500	0.107	20 125
		No. 6....	1.250	3 200	50 100	0.087	20 375
		No. 7....	0.750	1 385	100 500	0.161	24 375
		No. 8....	0.750	1 210	87 600	0.118	24 625
No. 4 ...	Grid Iron............	No. 1....	2.250	13 660	36 670	.....	13 375
		No. 2....	2.250	13 650	36 300	.....	13 750
		No. 3....	1.750	7 700	43 800	.....	16 375
		No. 4....	1.750	7 870	44 800	.....	14 250
		No. 5....	1.250	3 410	53 300	.....	17 000
		No. 6....	1.250	3 500	54 800	.....	17 750
		No. 7....	0.750	1 200	87 800	0.062	24 250
		No. 8....	0.750	missing	......	.....	missing

[a] All tension test specimens machined to 0.505 in. in diameter.

Respectfully submitted on behalf of the sub-committee,

J. L. JONES,
Chairman.

DISCUSSION

Mr. MacPherran.

MR. R. S. MACPHERRAN[1] (*Chairman, Committee A-3*).—Referring to the report on Correlation Tension and Transverse Tests of Cast Iron, I wish to point out that the curve shown in Fig. 1 of the report shows a decided drop in tensile strength as the diameter of test bar increases. This curve will vary somewhat, however, with the grade of iron used. The strength of a steel bar is a function of its composition and heat treatment. The strength of a cast-iron bar is also a function of its composition and heat treatment or "its cooling conditions." In considering a test bar, therefore, of rather soft and weak iron, the percentage of its strength, due to cooling conditions, is somewhat greater than where an iron is used whose composition gives naturally a harder and stronger iron and whose strength therefore is due, in a greater degree, to its composition.

To bring this out a little more clearly, a series of bars of quite soft iron (Grade C) of silicon 2.32 per cent and another series of fairly hard iron (Grade A) with silicon 1.11 per cent were made by our company. The chemical composition is given below:

	GRADE A IRON	GRADE C IRON
Total Carbon, per cent	3.43	3.42
Silicon, per cent	1.11	2.32
Sulfur, per cent	0.091	0.089
Manganese, per cent	0.53	0.54
Phosphorus, per cent	0.21	0.65

The sizes of the bars cast were about the same as those described in the report. All bars were cast vertically in cores, and the tension test bars were turned to 0.505 in. without throwing the center in turning.

Three tension bars of each size were used in each series. The results of tension tests on these bars are given below:

	DIAMETER AS CAST			
	$\frac{13}{16}$ IN.	$1\frac{1}{4}$ IN.	$1\frac{3}{4}$ IN.	$2\frac{1}{4}$ IN.
Grade A Iron	42 170	34 600	27 800	24 470
Grade C Iron	28 100	21 130	16 770	13 570

The test data have been plotted in the accompanying Fig. 1. The curve for the very soft iron (Grade C) showed about the same drop in tensile strength as shown in the report, but the curve

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[1] Chief Chemist, Allis-Chalmers Manufacturing Co., West Allis, Wis.

Mr. MacPherran. for the harder iron (Grade A) shows a somewhat less percentage difference from the small to the large bar. The tensile strength of the harder iron varied from 42,170 to 24,470 lb. per sq. in. The tensile strength of the softer iron varied from 28,100 to 13,570 lb. per sq. in. The exact percentage of loss was 42 per cent for the harder iron and 52 per cent for the softer iron. It will be noted that the actual loss is greater for the harder iron, but the relative loss is much less. Based on our experience in taking bars out of large castings, these results would be about normal.

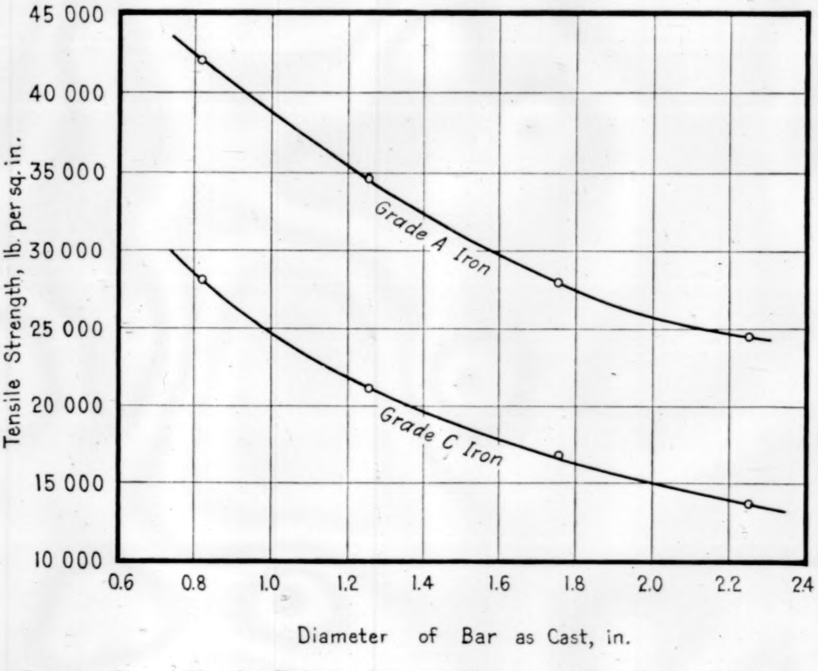

FIG. 1.—Curves Showing Relation Between Diameter of Test Bar as Cast and Tensile Strength for Cast Iron.

This difference in the curve is even more pronounced for high-test irons, which are usually quite low in carbon and sometimes contain various alloys. The strength of the various sections of those irons show less variation than in the above examples. Further work on this matter should be carried out, however, and I hope that next year material of great interest can be reported to the Society along this line.

REPORT OF COMMITTEE A-4
ON
HEAT TREATMENT OF IRON AND STEEL

During the past year the work of the committee has been transacted by mail and no meetings have been held.

The committee recommends that the present Tentative Definitions of Terms Relating to Heat Treatment Operations (A 119 – 27 T)[1] be revised to include the following additions and that the revised tentative definitions be continued as tentative for another year:

Insert after the definition of the term "annealing" definitions of the terms "full annealing" and "process annealing" to read as follows:

Full Annealing.—Heating iron-base alloys above the critical temperature range, holding above that range for a proper period of time followed by slow cooling through the range.

NOTE.—The annealing temperature is generally about 100° F. (55° C.) above the upper limit of the critical temperature range, and the time of holding is usually not less than one hour for each inch of section of the heaviest objects being treated. The objects being treated are ordinarily allowed to cool slowly in the furnace. They may, however, be removed from the furnace, and cooled in some medium which will prolong the time of cooling as compared to unrestricted cooling in the air.

Process Annealing.—Heating iron-base alloys to a temperature below or close to the lower limit of the critical range followed by cooling as desired.

NOTE.—This heat treatment is commonly applied in the sheet and wire industries and the temperatures generally used are from 1020 to 1200° F. (550 to 650° C.).

Insert after the definition of the term "normalizing" a definition of the term "patenting" to read as follows:

Patenting.—Heating iron-base alloys above the critical temperature range followed by cooling to below that range in molten lead maintained at a temperature of about 700° F. (365° C.).

NOTE.—This treatment is usually applied in the wire industry either as a finishing treatment or especially in the case of eutectoid steel as a treatment previous to further wire drawing. Its purpose is to produce a sorbitic structure.

The additions to the tentative definitions were approved by the Joint Committee on Definitions of Terms Relating to Heat Treatment consisting of three representatives of the American Society for Testing Materials, three representatives of the American Society for Steel Treating and three representatives of the Society of Automotive Engineers. On letter ballot in this joint committee, 7 voted affirmatively and 2 negatively. All three of the representatives of the American Society for Testing Materials voted affirmatively.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 703 (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 88.

The proposed revisions have been submitted to letter ballot of Committee A-4, which consists of 41 members, of whom 28 have voted affirmatively, 1 negatively, and 12 have refrained from voting.

The following officers have been elected for the next two years:

H. M. Boylston, chairman.
John H. Hall, vice-chairman-secretary.

This report has been submitted to letter ballot of the committee, which consists of 41 members; 31 members returned their ballots, of whom 30 have voted affirmatively, none negatively, and 1 has marked his ballot "not voting."

Respectfully submitted on behalf of the committee,

H. M. BOYLSTON,
Chairman.

J. H. HALL,
Secretary.

EDITORIAL NOTE

The proposed revisions of the Tentative Definitions of Terms Relating to Heat Treatment Operations were accepted. The tentative definitions in their revised form appear on page 759.

REPORT OF COMMITTEE A-5
ON
CORROSION OF IRON AND STEEL

The work of Committee A-5 during this year has been full of interest and all of its projects have been moving forward with enthusiasm and substantial developments.

Sub-Committee III on Inspection of the Fort Sheridan and Annapolis Tests reports additional failures and presents extension of tables giving the results for the various sheets grouped as regarding the presence of copper.

At Fort Sheridan the new failures are practically all in the light gage material and are about evenly divided as regarding copper and non-copper-bearing material in the open-hearth and pure iron groups. At the April inspection all of the non-copper-bearing sheets had failed and in the copper-bearing sheets two entire groups had failed and one other group had eight failures in a total of fourteen sheets exposed. It is observed, however, that the failures in copper-bearing sheets have been in the main within the past year after 126 and 132 months' exposure, whereas the non-copper-bearing groups have been showing failures in substantial numbers each year since the end of the first 37 months of the test.

All of the failures in the No. 16 gage sheets are in one group of non-copper-bearing material, the AA sheets designated as non-copper-bearing bessemer steel.

Due to the urgent need of the United States War Department for building purposes, the ground space on which the test at Fort Sheridan is located was relinquished following the April, 1928, inspection. Representative sheets from the different groups of metal exposed at this location have been salvaged for any future work of the committee in its contemplated study of rust formations and pitted surfaces. It was the unanimous opinion of the sub-committee that the test could not be moved without serious damage that would give uncertainty to any future corrosion developments. Furthermore, it was felt that the test had served all practical purposes of the original intent of determining the comparative behavior under the atmospheric conditions prevailing at the location of the same base types of iron and steel with and without copper contents. The sub-committee report gives a tabulation indicating the order of resistance of sheets at the Fort Sheridan location which may be compared with similar ratings at the Pittsburgh location when it was abandoned in March, 1923. It will be observed that the groups at these two locations have arranged themselves in substantially the same order as regarding failure under atmospheric conditions. The discontinuation of the Pittsburgh tests on March 9, 1923, and of the Fort Sheridan tests on April 16, 1928, after both tests had served their purpose, leaves remaining the Annapolis test for further study. The rate of corrosion continues slow at Annapolis with very few additional failures during the past year.

Sub-Committee V on Total Immersion Tests is reporting the final results of the immersion tests at Washington, D. C., and additional failures at Annapolis, Md. The Annapolis test is nearing completion, 132 out of 150 specimens having failed. The completed results of the Washington test, as shown in Table II, where the specimens were submerged in city water, as well as previous findings where the specimens were submerged in mine drainage and brackish water, confirm previous findings that corrosion resistance of iron and steel when submerged is practically uninfluenced by copper contents within the range of the tests.

The No. 22 gage sheet samples immersed in sea water at Key West, Fla., have shown a few failures, but no conclusions can be drawn at this time.

No failures have been reported so far on sheet samples immersed at Portsmouth, N. H.

The ship plates and tubes immersed in salt water at Key West, Fla., Portsmouth, N. H., and Port Arthur, Tex., have also been inspected during the year. No conclusions can be drawn in regard to any of these materials at this time.

Sub-Committee VI on Specifications for Zinc-Coated Products has continued its study of wire and wire products and offers two new Tentative Specifications for Zinc-Coated (Galvanized) Barb Wire and Zinc-Coated (Galvanized) Steel Wire Strand which are recommended by Committee A-5 for publication as tentative as appended hereto.[1] Substantial progress has been made in the study of zinc-coated (galvanized) guy and messenger strand wire for telephone, telegraph and signal use, road guard cable and road guard fabric, and specifications for these products will appear in the near future.

Sub-Committee VII on Methods of Tests, the activities of which are largely of a research nature, has continued its work in physical tests of coatings and has outlined work in an effort to simplify or modify the present standard methods of determining weights of coating on zinc-coated articles. The program of the section on corrosion testing methods calls for extensive study of the most promising type of accelerated weathering test apparatus.

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[1] See pp. 741 and 744, respectively.—ED.

In response to inquiries for some expression at this time concerning the trustworthiness of the rapid tests of materials by acid immersion, the committee at its meeting in Washington on March 22, 1928, on the unanimous recommendation of Sub-Committee VII on Methods of Testing, unanimously endorsed the following resolution:

WHEREAS, Inquiries as to the position of the American Society for Testing Materials relative to the trustworthiness of the accelerated acid test as a measure of natural corrosion have been referred to this committee for recommendation, and

WHEREAS, The continued functioning, during the past twenty years, of Committee A-5 and its sub-committees dealing with this subject, has developed no further information as to the relation of the accelerated acid test to corrosion by the elements, be it

RESOLVED, That Committee A-5 finds no reason for any change in its attitude towards this test as expressed in its annual report for 1911, which was as follows:

> "Notwithstanding the fact that this Committee, in its annual report of 1909, pointed out as clearly as it could that the tentative suggestions made by it in 1907 as to the conditions for carrying out the so-called acid corrosion test were not to be considered a recommendation of the test, and that the results of such test are unreliable as truly measuring the tendency to natural corrosion, the name of the American Society for Testing Materials continues to be used as having recommended the acid corrosion test, and by inference as having endorsed the same. For this reason the Committee desires at this time to again disclaim any recommendation or endorsement of the acid test as a measure of natural corrosion, and to point out that any use of the name or authority of the American Society for Testing Materials in this connection is unwarranted."

Sub-Committee VIII on Field Tests of Metallic Coatings has inspected the galvanized sheet tests at Pittsburgh, Pa., Altoona, Pa., State College, Pa., Sandy Hook, N. J., and Key West, Fla., twice during the year, and has accumulated a large amount of valuable information. No extensive detailed results are given since it is felt that the findings as developed in the relatively short period of exposure do not justify the printing that would be required. The collection of the specimens of coated wire, fencing, conduit, pipe, bolts, hardware and fittings, roofing nails and wood screws, and structural shapes will be completed and the samples placed on the racks within the next few months. This work continues to attract widespread interest and gives promise of reliable data on the corrosion resistance of various coatings under atmospheric service conditions.

Sub-Committee IX on Metal Culvert Corrosion Tests is reporting satisfactory progress in its investigations of sources of information on this important engineering material. The state highway departments and the railroads, constituting the largest consumers of culverts, have expressed deep interest in further work which may more definitely determine the comparative values of the different types of base metals used in culvert construction under varying soil and other service conditions. A number of locations have been placed at the disposal of the sub-committee for field tests, and we may confidently look forward to interesting and valuable developments from this undertaking in the near future.

The committee records with profound sorrow their deep sense of loss in the death of William A. Cooper who passed away on December 29, 1927. Mr. Cooper had been an active member of the committee for many years and had been chairman of Sub-Committee V on Immersion Tests since its organization in 1915. His cheerful spirit, fair-minded attitude and unselfish devotion to the work has contributed largely to its success, and earned for him the deep respect and confidence of his associates. His memory will be a lasting inspiration to his friends.

The present officers of the committee have been re-elected for the ensuing two years.

The following is the result of the letter ballot of the committee on the recommendations made in this report.

Items	Affirmative	Negative	Not Voting
PROPOSED NEW TENTATIVE STANDARDS			
Proposed Tentative Specifications for Zinc-Coated (Galvanized) Steel Wire Strand	62	3	15
Proposed Tentative Specifications for Zinc-Coated (Galvanized) Barb Wire............	59	2	19

This report has been submitted to letter ballot of the committee, which consists of 104 members; 80 members returned their ballots, of whom 77 have voted affirmatively, 1 negatively, and 2 have marked their ballots "not voting."

Respectfully submitted on behalf of the committee,

J. H. GIBBONEY,
Chairman.

JAMES ASTON,
Secretary.

EDITORIAL NOTE

The proposed Specifications for Zinc-Coated (Galvanized) Barb Wire; and for Zinc-Coated (Galvanized) Steel Wire Strand were accepted for publication as tentative and appear on pages 741 and 744, respectively.

REPORT OF SUB-COMMITTEE III ON INSPECTION OF THE FORT SHERIDAN AND ANNAPOLIS TESTS

Sub-Committee III on Inspection has held two meetings during the past year.

First Meeting

The first meeting was held at Annapolis, Md., on October 5, 1927, with Messrs. Cooper, Gibboney, Passano, Smith, Taylerson, and Thompson representing the Bureau of Steam Engineering of the United States Navy Department, present; Messrs. Fleming, McDonnell and Wheaton being absent. The following additional failures were recorded:

Sheet O-7 (No. 22 gage Low-Copper Open-hearth Steel, Series A) failed due to small holes in lower left first corrugation.

Sheet O-10 (No. 22 gage Low-Copper Open-hearth Steel, Series A) failed due to ragged edges at the bottom of the sheet.

Sheet S-13 (No. 22 gage Low-Copper Pure Iron, Series B), manufactured by the American Rolling Mill Co., failed due to a hole in the lower right corner.

It was noted in the case of Sheet S-14 (No. 22 gage Low-Copper Pure Iron, Series B) recorded as a failure in March 1926, due to a broken lower right corner, that corrosion has not progressed appreciably in this zone. Sheet B-4 (No. 22 gage Copper-Bearing Open-hearth Steel, Series A) was recorded as a failure in March 1925, due to a broken upper left corner, but corrosion has not progressed appreciably in this corner of the sheet. Since no further progress of corrosion has occurred in these two sheets in the zone of recorded failures there is reasonable ground for considering that the small broken corners may have been due to some mechanical damage since placing the sheets on the racks.

Sheet B-4 (No. 22 gage Copper-Bearing Open-hearth Steel, Series A) was recorded a failure in March 1925, and through error has been shown in the tabulation of failures under the non-copper-bearing sheets. This error crept into the report on account of the B group sheets containing three sheets classified as non-copper-bearing and nine sheets copper-bearing. The error is corrected in this report and sheet B-4 is now shown in the copper-bearing failures.

Messrs. Cooper, Smith and Thompson made a careful detailed inspection of the sheets as regarding a color development in connection with the appearance of a bluish gray scale on some of the groups

TABLE I.—CLASSIFICATION ACCORDING TO COLOR OF SHEETS EXPOSED AT ANNAPOLIS.

COLOR	NO. 22 GAGE SHEETS	NO. 16 GAGE SHEETS
Light	Sheets D-1, 5, 7, 8, 9, 12, 14	Sheets AA-1 to 9, incl.
		Sheets AA-31 to 39, incl.[a]
	Sheets S-1 to 14, incl.	Sheets SS-1 to 14, incl.
	Sheets X-1 to 14, incl.	Sheets CC-5, 6, 8
	Sheets A-4 to 15, incl.	Sheets CC-20 to 25, incl.[a]
	Sheets B-4, 6, 7, 8	Sheets DD-4, 11 to 15, incl.
	Sheets C-4, 5, 15, 16, 17, 23 to 26, incl.	Sheets DD-32, 33, 41, 42, 43[a]
	Sheets H-4 to 14, incl., 16, 18	Sheets HH-4 to 9, incl.
	Sheets M-4 to 14, incl.	Sheets UU-4 to 9, incl.
	Sheets U-4 to 14, incl.	Sheets VV-4, 7 to 14, incl.
	Sheets V-4 to 14, incl.	Sheets XX-4 to 14, incl.
	Sheets O-4 to 12, incl.	Sheets ZZ-1, 2, 4
	Sheets Z-417, 418, 419	Sheets OO-12
		Sheets CCC-36
		Sheets CCC-28 to 35, incl.[a]
		Sheets YY-1, 2, 3
Medium	Sheets A-1, 2, 3	Sheets BB-1, 2, 3, 37, 10 to 14, incl.
	Sheets B-1, 2, 3, 24 to 28, incl.	Sheets BB-25 to 28, incl.[a]
	Sheets C-1, 2, 3	Sheets BB-42 to 45, incl.[a]
	Sheets H-1, 2, 3	Sheets CC-1, 3, 4
	Sheets M-1, 2, 3	Sheets DD-1, 2, 3
	Sheets T-1 to 14, incl.	Sheets DD-34 to 38, incl.[a]
	Sheets U-1, 2, 3	Sheets EE-4, 5, 6
	Sheets V-1, 2, 3	Sheets HH-1, 2, 3
	Sheets O-1, 2, 3	Sheets HH-27 to 33, incl.[a]
	Sheets Z-1, 2, 3	Sheets KK-9, 10, 11
	Sheets I-4, 5	Sheets MM-1 to 14, incl.
	Sheets K-4 to 16, incl.	Sheets TT-1 to 14, incl.
	Sheets Y-1, 2, 3	Sheets UU-1, 2, 3, 10 to 14, incl.
	Sheets Z-101, 102 , 108, 202, 204, 260	Sheets VV-1, 2, 3, 5, 6
	Sheets Z-501, 503, 504, 602, 603, 604	Sheets XX-1, 2, 3
		Sheets OO-1 to 11, incl.
		Sheets CCC-25, 26, 27
		Sheets ZZ-501, 502, 503
		Sheets ZZ-201, 202, 204
		Sheets ZZ-710 711
		Sheets ZZ-102, 103
		Sheets ZZ-417, 418, 419
Dark	Sheets E-1 to 11, incl.	Sheets EE-1, 2, 3
	Sheets I-1, 2, 3, 6 to 16, incl.	Sheets EE-19 to 24, incl.[a]
	Sheets K-1, 2, 3	Sheets II-1 to 8, incl.
	Sheets Z-301, 303, 305	Sheets II-30 to 37, incl.[a]
	Sheets Z-702, 705, 707	Sheets KK-1, 2, 3, 12 to 15, incl.
		Sheets KK-35 to 42, incl.[a]
		Sheets ZZ-306, 307
		Sheets ZZ-602, 605

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[a] Sand blasted.

of sheets. They have classified the groups in accordance with this scale as light, medium and dark, the light indicating little or no blue scale, the dark a large preponderance of bluish gray scale, and medium an intermediate condition. Since this condition may lead to some future study of rust condition, the gradings as found by these inspectors are given in Table I.

The sheets at Fort Sheridan, Ill., were inspected on October 26, 1927, by Messrs. Fleming, Smith and Taylerson; Messrs. Cooper, Gibboney, McDonnell, McAdam, Passano and Wheaton being absent. The following additional failures were recorded:

Sheet AA-12 (No. 16 gage Low-Copper Bessemer Steel, Series A) failed due to small hole near the bottom of the sheet.

Sheet AA-20 (No. 16 gage Low-Copper Bessemer Steel, Series A) failed due to a large laminated area cracked and rusted over lower rail.

Sheet C-7 (No. 22 gage Copper-Bearing Pure Iron, Series A) failed due to crack and holes in lower portion, aside from some mechanical damage.

Sheet D-24 (No. 22 gage Low-Copper Pure Iron, Series A) failed due to cracked hole near the bottom of the sheet.

Sheet D-27 (No. 22 gage Low-Copper Pure Iron, Series A) failed due to hole near the bottom of the sheet.

Sheet E-15 (No. 22 gage Copper-Bearing Puddled Iron, Series A) failed due to small hole near the bottom of the sheet.

Sheet U-15 (No. 22 gage Copper-Bearing Pure Iron, Series B), manufactured by the Allegheny Steel Co., failed due to small hole near the bottom of the sheet.

Sheets U-17, 23, 24 and 25 (No. 22 gage Copper-Bearing Pure Iron, Series B), manufactured by the Allegheny Steel Co., failed due to large cracked holes near the bottom of the sheets.

Sheets V-17, 25 and 28 (No. 22 gage Copper-Bearing Pure Iron, Series B), manufactured by the Whitaker-Glessner Co., failed due to cracks near the bottom of the sheets.

Sheets X-18 and 19 (No. 22 gage Low-Copper Pure Iron, Series B), manufactured by the Inland Steel Co., failed due to cracks and holes near the bottom of the sheets.

Sheet X-21 (No. 22 gage Low-Copper Pure Iron, Series B), manufactured by the Inland Steel Co., failed due to a hole near the bottom of the sheet.

No detailed record covering the condition of the sheets at Fort Sheridan as regarding texture, color and adherence of rust was made since no appreciable changes as compared with previous records was observed. No photographic records of failed sheets were made at the Annapolis or Fort Sheridan inspections.

SECOND MEETING

The second meeting was held at Fort Sheridan, Ill., on April 16, 1928, with Messrs. Fleming, Gibboney, McDonnell, Passano, Smith and Taylerson present; Messrs. McAdam and Wheaton being absent. The following additional failures were recorded:

Sheet A-27 (No. 22 gage Low-Copper Bessemer Steel, Series A) failed due to holes in the bottom of the sheet.

Sheet D-25 (No. 22 gage Low-Copper Pure Iron, Series A), failed due to longitudinal crack near the bottom of the sheet.

Sheet T-28 (No. 22 gage Copper-Bearing Open-hearth Steel, Series B), manufactured by the Newport Rolling Mill Co., failed due to hole near the bottom of the sheet.

Sheet U-18 (No. 22 gage Copper-Bearing Pure Iron, Series B), manufactured by the Allegheny Steel Co., failed due to small holes near the bottom of the sheet.

Sheet V-18 (No. 22 gage Copper-Bearing Pure Iron, Series B), manufactured by the Whitaker-Glessner Co., failed due to longitudinal crack near the bottom of the sheet.

It was observed that a fairly large number of the light gage sheets, not showing defects at this time to be classified as failures under the standard method of grading were nevertheless so thin from corrosion that ultimate failure was only the matter of a very short time. It was decided that since the test was being abandoned these thin sheets would be given light bending stresses simulating wind pressure or snow load, and where structural breakdown with transverse cracking resulted all such sheets would be classified as failures. Under this test the following sheets were recorded as failures:

Sheets B-13, 14, 15, 16, 31, 32 and 33 (No. 22 gage Low-Copper Open-hearth Steel, Series A).

Sheets C-18 and 19 (No. 22 gage Pure Iron, Series A) classified as non-copper bearing due to copper content below 0.15 per cent.

Sheets C-9, 10, 27, 28, 29, 30 and 31 (No. 22 gage Pure Iron, Series A) classified as copper bearing due to copper content above 0.15 per cent.

Sheets M-15 and 17 (No. 22 gage Copper-Bearing Open-hearth Steel, Series B), manufactured by the Alan Wood Iron and Steel Co.

Sheets T-15, 16, 17, 20, 24, 26 and 27 (No. 22 gage Copper-Bearing Open-hearth Steel, Series B), manufactured by the Newport Rolling Mill Co.

Sheets U-20, 22, 26, 27 and 28 (No. 22 gage Copper-Bearing Pure Iron, Series B), manufactured by the Allegheny Steel Co.

Sheets V-15, 16, 19, 20, 21, 22, 23, 24, 26 and 27 (No. 22 gage Copper-Bearing Pure Iron, Series B), manufactured by the Whitaker-Glessner Co.

Due to the urgent need of the United States War Department for building purposes the ground space on which the test at Fort Sheridan is located was relinquished following the April 16, 1928, inspection. Representative sheets from the different groups of metal exposed at this location have been salvaged for any future work of the committee in its contemplated study of rust formations and pitted surfaces. It was the unanimous view of the sub-committee that the test could not be moved without serious damage that would give uncertainty to any future corrosion developments. Furthermore, that the test had served all practical purposes of the original intent of determining the comparative behavior under the atmospheric conditions prevailing at the location of the same base types of iron and steel with and without copper content, and that the test location should be abandoned.

The following sheets removed from the Fort Sheridan test racks have been carefully marked, securely crated and will be available for any future investigations of the sub-committee; all other sheets have been scrapped:

NO. 22 GAGE: Sheets A-20, 21, 28; B-9, 11, 12; C-6, 7, 8; D-24, 25, 28; E-22, 23, 24; H-23, 24, 25; I-19, 20, 21; K-17, 18, 19; M-15, 16, 25; O-18, 19; T-15, 16, 17; U-18, 19, 20; V-26, 27, 28; X-20, 21, 22; Y-5, 6; Z-4, 5, 109, 110, 207, 208, 306, 308, 420, 506, 508, 605, 606, 709.

NO. 16 GAGE: Sheets AA-14, 15, 16; BB-4, 5, 6; CC-2, 9, 10; CCC-13, 14, 15; DD-5, 6, 7; EE-28, 29, 30; HH-16, 17, 18; II-10, 11, 12; KK-4, 5, 21; MM-15, 16, 17; OO-13, 14, 15; SS-15, 16, 17; TT-15, 16, 17; UU-15, 16, 17; VV-20, 21, 22; XX-15, 16, 17; YY-4, 5, 6; ZZ-5, 7, 106, 205, 308, 309, 420, 422, 505, 506, 610, 611, 712, 713.

Table II, Plate I, is presented as a continuation of the same general plan of grouping the sheets at Fort Sheridan as regarding the presence of copper and recording the failures at all inspection periods. It will be observed that after eleven years' exposure all of the sheets classified as non-copper bearing have failed with the exception of four sheets in Group B Open-hearth Steel (copper content 0.103 per cent) and two sheets in Group Z Bessemer Steel (copper content 0.130 per cent). In the sheets classified as copper bearing 50 of a total of 136 have failed, and 44 of the 50 failures have occurred after ten years' exposure.

Table III is presented as indicating the order of resistance of uncoated sheets to corrosion under atmospheric exposure as recorded

TABLE II.—FAILURES AT FORT SHERIDAN TESTS. INSPECTIONS OF 1917, 1918, 1919, 19

Group	Designation	Series	Description	Average Analysis, per cent						Number of Sheets in Test		
				Carbon	Manganese	Phosphorus	Sulfur	Silicon	Copper		Mar. 31, 1919.[a] 24 Months	Dec. 6, 1919. 32 Months
EE	Puddled Iron	A	Copper-Bearing	0.035	0.03	0.119	0.018	0.125	0.319	12	None	None
HH	Copper-Bearing Basic Open-hearth Steel	A	" "	0.074	0.373	0.011	0.026	0.004	0.237	17	None	None
II	Copper-Bearing Bessemer Steel	A	" "	0.059	0.371	0.095	0.066	0.006	0.247	19	None	None
KK	Copper-Bearing Acid Open-hearth Steel	A	" "	0.108	0.433	0.085	0.043	0.005	0.234	19	None	None
CCC	Copper-Bearing Pure Iron	A	" "	0.023	0.026	0.005	0.028	0.005	0.236	12	None	None
TT	Copper-Bearing Steel, Newport Rolling Mill Co.	B	" "	0.080	0.313	0.009	0.020	0.006	0.223	14	None	None
UU	Copper-Bearing Pure Iron, Allegheny Steel Co.	B	" "	0.018	0.066	0.008	0.028	0.005	0.239	13	None	None
VV	Copper-Bearing Pure Iron Whitaker-Glessner Co.	B	" "	0.018	0.046	0.007	0.019	0.004	0.299	19	None	None
ZZ	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co.	B	" "	0.08	0.40	0.091	0.035	0.006	0.154	1	None	None
ZZ	Copper-Bearing Bessemer Steel Youngstown Sheet and Tube Co.	B	" "	0.08	0.34	0.094	0.037	.....	0.279	2	None	None
ZZ	Copper-Bearing Bessemer Steel Youngstown Sheet and Tube Co.	B	" "	0.07	0.36	0.082	0.033	.....	0.528	2	None	None
ZZ	Copper-Bearing Open-hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.06	0.37	0.050	0.052	.....	0.172	2	None	None
ZZ	Copper-Bearing Open-hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.09	0.34	0.038	0.077	0.003	0.641	2	None	None
ZZ	Copper-Bearing Open-hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.06	0.39	0.049	0.044	.....	0.318	2	None	None
	Total	.....	.....	.....	.....	.....	.....	.....	.....	136	None	None
AA	Bessemer Steel	A	Non-Copper-Bearing	0.043	0.419	0.083	0.042	0.004	0.012	17	None	None
BB	Open-hearth Steel	A	" " "	0.056	0.349	0.022	0.048	0.037	0.129	17	None	None
CC	Copper-Bearing Pure Iron	A	" " "	0.019	0.029	0.004	0.032	0.003	0.067	12	None	None
DD	Low-Copper Pure Iron	A	" " "	0.019	0.028	0.004	0.027	0.004	0.028	19	None	None
OO	Low-Copper Open-hearth Steel	A	" " "	0.108	0.371	0.009	0.029	0.007	0.029	12	None	None
MM	Open-hearth Steel, Alan Wood Iron and Steel Co.	B	" " "	0.017	0.414	0.010	0.029	0.007	0.057	14	None	None
SS	Low-Copper Pure Iron, American Rolling Mill Co.	B	" " "	0.017	0.021	0.006	0.021	0.006	0.025	12	None	None
XX	Low-Copper Pure Iron, Inland Steel Co.	B	" " "	0.021	0.062	0.008	0.030	0.005	0.028	14	None	None
YY	Low-Copper Wrought Iron, Youngstown Sheet and Tube Co.	B	" " "	0.03	0.051	0.123	0.019	0.203	0.023	3	None	None
ZZ	Bessemer Steel, Youngstown Sheet and Tube Co.	B	" " "	0.08	0.45	0.102	0.037	0.008	0.014	2	None	None
ZZ	Open-hearth Steel, Youngstown Sheet and Tube Co.	B	" " "	0.022	0.39	0.040	0.028	....	0.030	2	None	None
	Total	.....	.....	.....	.....	.....	.....	.....	.....	124	None	None
B	Open-hearth Steel	A	Copper-Bearing	0.06	0.27	0.014	0.053	0.006	0.156	2	None	None
C	Copper-Bearing Pure Iron	A	" "	0.015	0.028	0.006	0.036	0.003	0.195	10	None	None
E	Puddled Iron	A	" "	0.033	0.034	0.114	0.021	0.134	0.283	12	None	None
H	Copper-Bearing Basic Open-hearth Steel	A	" "	0.069	0.387	0.016	0.027	0.004	0.244	11	None	None
I	Copper-Bearing Bessemer Steel	A	" "	0.041	0.365	0.097	0.068	0.008	0.252	19	None	None
K	Copper-Bearing Acid Open-hearth Steel	A	" "	0.107	0.447	0.091	0.046	0.004	0.237	16	None	None
M	Open-hearth Steel, Alan Wood Iron and Steel Co.	B	" "	0.093	0.419	0.013	0.041	0.011	0.185	14	None	None
T	Copper-Bearing Steel Newport Rolling Mill Co.	B	" "	0.083	0.313	0.009	0.020	0.005	0.227	14	None	None
U	Copper-Bearing Pure Iron, Allegheny Steel Co.	B	" "	0.017	0.074	0.008	0.037	0.005	0.260	14	None	None
V	Copper-Bearing Pure Iron, Whitaker-Glessner Co.	B	" "	0.018	0.051	0.007	0.021	0.005	0.304	14	None	None
Z	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co.	B	" "	0.06	0.37	0.094	0.038	0.007	0.263	2	None	None
Z	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co.	B	" "	0.05	0.37	0.114	0.048	.....	0.533	2	None	None
Z	Copper-Bearing Open-hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.06	0.35	0.049	0.059	.....	0.212	2	None	None
Z	Copper-Bearing Open-hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.06	0.39	0.047	0.047	.....	0.286	2	None	None
Z	Copper-Bearing Open-hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.07	0.41	0.042	0.042	.....	0.532	2	None	None
	Total	.....	.....	...				.....		136	None	None
A	Bessemer Steel	A	Non-Copper-Bearing	0.038	0.386	0.089	0.040	0.007	0.014	15	None	None
B	Open-hearth Steel	A	" " "	0.09	0.38	0.017	0.062	0.036	0.103	11	None	None
C	Copper-Bearing Pure Iron	A	" " "	0.01	0.028	0.002	0.027	0.002	0.144	2	None	None
D	Low-Copper Pure Iron	A	" " "	0.02	0.026	0.004	0.022	0.002	0.024	6	None	None
O	Low-Copper Open-hearth Steel	A	" " "	0.121	0.536	0.008	0.030	0.249	0.020	12	None	14, 15, 21 (3)
	Low-Copper Pure Iron, American Rolling Mill Co.	B	" " "	0.02	0.023	0.006	0.022	0.004	0.022	14	None	None
X	Low-Copper Pure Iron, Inland Steel Co.	B	" " "	0.021	0.055	0.007	0.031	0.004	0.027	14	None	None
Y	Low-Copper Wrought Iron, Youngstown Sheet and Tube Co.	B	" " "	0.03	0.055	0.139	0.021	0.218	0.020	3	None	None
Z	Bessemer Steel, Youngstown Sheet and Tube Co.	B	" " "	0.07	0.44	0.107	0.046	0.003	0.011	2	None	None
Z	Bessemer Steel, Youngstown Sheet and Tube Co.	B	" " "	0.06	0.38	0.077	0.035	0.009	0.130	2	None	None
Z	Open-hearth Steel, Youngstown Sheet and Tube Co.	B	" " "	0.06	0.32	0.065	0.044	0.002	0.018	2	None	None
	Total	.....	.....	....	....	.....	....	..	.....	83	None	3

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[1] In preparing this table, sheets below 0.15 per cent copper have been considered as non-copper-bearing, and those above 0.15 per cent copper as copper-bearing.

[a] No failures were recorded at inspections made prior to March 31, 1919; the detail records are accordingly not given here.

919, 1920, 1921, 1922, 1923, 1924, 1925, 1926, 1927, AND APRIL, 1928. SHEETS EXPOSED APRIL 9, 1917. COMPARING COPPER-BEARING WITH NON-COPPER-B

Date of Inspection

6, 1919. Months	May 10, 1920. 37 Months	Oct. 11, 1920. 42 Months	Apr. 4, 1921. 48 Months	Oct. 17, 1921. 54 Months	Apr. 10, 1922. 60 Months	Oct. 16, 1922. 66 Months	Mar. 8, 1923. 71 Months	Oct. 12, 1923. 78 Months	Apr. 16, 1924. 84 Months	Oct. 12, 1924. 90 Months	Mar. 11, 1925 95 Months	Sept. 18, 1925. 101 Months	Apr. 8, 1926 108 Months
				No. 16 GAGE SHEETS									
None	None	None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	13 (1)	None	None	None	None	None	None	None	11 (1)	None
one	None	None	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	1	None	None	None	None	None	None	None	1	None
				No. 22 GAGE SHEETS									
one	None	None	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None	6 (1)	None
one	None	None	None	None	None	None	None	None	None	None	None	13 (1)	None
one	None	None	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None	2	None
one	16, 17, 18 (3)	None	19, 29, 30, (3)	None	None	22 (1)	None	25 (1)	21 (1)	None	None	20, 23, 24, 26, 28 (5)	None
one	None	None	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	22 (1)	None	None	None	None	None	None	None
, 21 (3)	13, 16, 19, 23, 24 (5)	17, 18, 20, 22 (4)	....	....	....	....	....	....	....	....	....	....	....
one	None	None	None	16, 22, 25, 26, 28 (5)	17, 18, 19, 20, 21 23, 24. 27 (8)	15 (1)	....	....	....	....	....	....	....
one	None	None	25 (1)	None	None	15, 17 (2)	None	None	None	None	16 (1)	22, 23 (2)	24, 26, 28 (3)
one	None	4 (1)	None	None	None	None	None	6 (1)	None	None	None	5 (1)	....
one	None	None	4, 5 (2)	....	....	....	....	....	....	....	....	....	....
one	None	None	None	None	None	None	None	None	None	None	None	None	None
one	421 (1)	None	None	420 (1)	....	....	....	....	....	....	....	....	....
3	9	5	6	6	8	5	None	2	1	None	1	8	3

IONS OF 1917, 1918, 1919, 1920, 1921, 1922, 1923, 1924, 1925, 1926, 1927, AND APRIL, 1928. SHEETS EXPOSED APRIL 9, 1917. COMPARING C

umber f Sheets n Test	Date of Inspection											
	Mar. 31, 1919.[a] 24 Months	Dec. 6, 1919. 32 Months	May 10, 1920. 37 Months	Oct. 11, 1920. 42 Months	Apr. 4, 1921. 48 Months	Oct. 17, 1921. 54 Months	Apr. 10, 1922. 60 Months	Oct. 16, 1922. 66 Months	Mar. 8, 1923. 71 Months	Oct. 12, 1923. 78 Months	Apr. 16, 1924. 84 Months	Oct. 12, 1 90 Mont
						No. 16 GAGE SHEETS						
12	None	None	None	None	None	None	None	None	None	None	None	None
17	None	None	None	None	None	None	None	None	None	None	None	None
19	None	None	None	None	None	None	None	None	None	None	None	None
19	None	None	None	None	None	None	None	None	None	None	None	None
12	None	None	None	None	None	None	None	None	None	None	None	None
14	None	None	None	None	None	None	None	None	None	None	None	None
13	None	None	None	None	None	None	None	None	None	None	None	None
19	None	None	None	None	None	None	None	None	None	None	None	None
1	None	None	None	None	None	None	None	None	None	None	None	None
2	None	None	None	None	None	None	None	None	None	None	None	None
2	None	None	None	None	None	None	None	None	None	None	None	None
2	None	None	None	None	None	None	None	None	None	None	None	None
2	None	None	None	None	None	None	None	None	None	None	None	None
2	None	None	None	None	None	None	None	None	None	None	None	None
136	None	None	None	None	None	None	None	None	None	None	None	None
17	None	None	None	None	None	13 (1)	None	None	None	None	None	None
17	None	None	None	None	None	None	None	None	None	None	None	None
12	None	None	None	None	None	None	None	None	None	None	None	None
19	None	None	None	None	None	None	None	None	None	None	None	None
12	None	None	None	None	None	None	None	None	None	None	None	None
14	None	None	None	None	None	None	None	None	None	None	None	None
12	None	None	None	None	None	None	None	None	None	None	None	None
14	None	None	None	None	None	None	None	None	None	None	None	None
3	None	None	None	None	None	None	None	None	None	None	None	None
2	None	None	None	None	None	None	None	None	None	None	None	None
2	None	None	None	None	None	None	None	None	None	None	None	None
124	None	None	None	None	None	1	None	None	None	None	None	None
						No. 22 GAGE SHEETS						
2	None	None	None	None	None	None	None	None	None	None	None	None
10	None	None	None	None	None	None	None	None	None	None	None	None
12	None	None	None	None	None	None	None	None	None	None	None	None
11	None	None	None	None	None	None	None	None	None	None	None	None
19	None	None	None	None	None	None	None	None	None	None	None	None
16	None	None	None	None	None	None	None	None	None	None	None	None
14	None	None	None	None	None	None	None	None	None	None	None	None
14	None	None	None	None	None	None	None	None	None	None	None	None
14	None	None	None	None	None	None	None	None	None	None	None	None
14	None	None	None	None	None	None	None	None	None	None	None	None
2	None	None	None	None	None	None	None	None	None	None	None	None
2	None	None	None	None	None	None	None	None	None	None	None	None
2	None	None	None	None	None	None	None	None	None	None	None	None
2	None	None	None	None	None	None	None	None	None	None	None	None
2	None	None	None	None	None	None	None	None	None	None	None	None
136	None	None	None	None	None	None	None	None	None	None	None	None
15	None	None	16, 17, 18 (3)	None	19, 29, 30, (3)	None	None	22 (1)	None	25 (1)	21 (1)	None
11	None	None	None	None	None	None	None	None	None	None	None	None
2	None	None	None	None	None	None	None	None	None	None	None	None
6	None	None	None	None	None	None	None	22 (1)	None	None	None	None
12	None	14, 15, 21 (3)	13, 16, 19, 23, 24 (5)	17, 18, 20, 22 (4)	....	....	....	....	....	....	....	....
14	None	None	None	None	None	16, 22, 25, 26, 28 (5)	17, 18, 19, 20, 21 23, 24, 27 (8)	15 (1)	....	....	....	....
14	None	None	None	None	25 (1)	None	None	15, 17 (2)	None	None	None	None
3	None	None	None	4 (1)	None	None	None	None	None	6 (1)	None	None
2	None	None	None	None	4, 5 (2)	....	....	....	....	....	....	....
2	None	None	None	None	None	None	None	None	None	None	None	None
2	None	None	421 (1)	None	None	420 (1)	....	....	....	....	....	....
83	None	3	9	5	6	6	8	5	None	2	1	None

PLATE I.
PROC. AM. SOC TESTING MATS.
VOL. 28, PART I.
REPORT OF COMMITTEE A-5:
CORROSION TESTS.

ring Copper-Bearing with Non-Copper-Bearing Materials.[1]

Oct. 12, 1924. 90 Months	Mar. 11, 1925 95 Months	Sept. 18, 1925. 101 Months	Apr. 8, 1926 108 Months	Sept. 24, 1926. 113 Months	Mar. 28, 1927. 119 Months	Oct. 26, 1927. 126 Months	Apr. 16, 1928. 132 Months	Number of Sheets Failed in Test
None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None
None	None	11 (1)	None	None	None	12, 20 (2)	None	4
None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None
None	None	1	None	None	None	2	None	4
None	None	None	None	None	None	None	None	None
None	None	6 (1)	None	None	8 (1)	7 (1)	9, 10, 27, 28, 29, 30, 31 (7)	10 (all)
None	None	13 (1)	None	None	None	15 (1)	None	2
None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	15, 17 (2)	2
None	None	None	None	None	None	None	15, 16, 17, 20, 24, 26, 27, 28 (8)	8
None	None	None	None	None	16, 19, 21 (3)	15, 17, 23, 24, 25 (5)	18, 20, 22, 26, 27, 28 (6)	14 (all)
None	None	None	None	None	None	17, 25, 28 (3)	15, 16, 18, 19, 20, 21, 22, 23, 24, 26, 27 (11)	14 (all)
None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None
None	None	2	None	None	4	10	34	50
None	None	20, 23, 24, 26, 28 (5)	None	None	None	None	27 (1)	15 (all)
None	None	None	None	None	None	None	13, 14, 15, 16, 31, 32, 33 (7)	7
None	None	None	None	None	None	None	18, 19 (2)	2 (all)
None	None	None	None	16, 18 (2)	None	24, 28 (2)	25 (1)	6 (all)
....	....	....	....	....	....	....	....	12 (all)
....	....	....	....	....	....	....	....	14 (all)
None	16 (1)	22, 23 (2)	24, 26, 28 (3)	27 (1)	20 (1)	18, 19, 21 (3)	....	14 (all)
None	None	5 (1)	....	....	....	....	....	3 (all)
....	....	....	....	....	....	....	....	2 (all)
None	None	None	None	None	None	None	None	None
....	....	....	....	....	....	....	....	2 (all)
None	1	8	3	3	1	5	11	77

TABLE V.—FAILURES AT PITTSBURGH TESTS. INSPECTIONS OF 1917, 1918, 1919, 1920, 1921, 1922 AND MARCH, 1923. SH

Group.	Designation.	Series.	Description.	Average Analysis.						Number of Sheets in Test.		
				Carbon.	Manganese.	Phosphorus.	Sulfur.	Silicon.	Copper.		Oct. 9, 1917. 10 Months.	April 16 M
											No. 16 GAGE	SHEE
EE	Puddled Iron	A	Copper-Bearing	0.035	0.03	0.119	0.018	0.125	0.319	12	None	N
HH	Copper-Bearing Basic Open-hearth Steel	A	" "	0.074	0.373	0.011	0.026	0.004	0.237	15	None	N
II	Copper-Bearing Bessemer Steel	A	" "	0.059	0.371	0.095	0.066	0.006	0.247	18	None	N
KK	Copper-Bearing Acid Open-hearth Steel	A	" "	0.108	0.433	0.085	0.043	0.005	0.234	19	None	N
CCC	Copper-Bearing Pure Iron	A	" "	0.023	0.026	0.005	0.028	0.005	0.236	12	None	N
TT	Copper-Bearing Steel, Newport Rolling Mill Co.	B	" "	0.080	0.313	0.009	0.020	0.006	0.223	14	None	N
UU	Copper-Bearing Pure Iron, Allegheny Steel Co.	B	" "	0.018	0.066	0.008	0.028	0.005	0.239	14	None	N
VV	Copper-Bearing Pure Iron, Whitaker-Glessner Co.	B	" "	0.018	0.046	0.007	0.019	0.004	0.299	13	None	N
ZZ	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co.	B	" "	0.08	0.40	0.092	0.037	0.004	0.153	1	None	N
ZZ	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co.	B	" "	0.09	0.31	0.088	0.047	.....	0.271	3	None	N
ZZ	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co.	B	" "	0.07	0.36	0.085	0.033	.....	0.549	3	None	N
ZZ	Copper-Bearing Open-hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.06	0.37	0.054	0.064	.....	0.223	3	None	N
ZZ	Copper-Bearing Open-hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.09	0.33	0.032	0.056	0.003	0.575	3	None	N
ZZ	Copper-Bearing Open-hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.07	0.40	0.056	0.048	.....	0.364	2	None	N
	Total	.....	.....	.....	.....	.....	.....	.....	.....	132	None	N
AA	Bessemer Steel	A	Non-Copper-Bearing	0.043	0.419	0.083	0.042	0.004	0.012	17	None	N
BB	Open-hearth Steel	A	" " "	0.056	0.349	0.022	0.048	0.037	0.113	17	None	N
CC	Copper-Bearing Pure Iron	A	" " "	0.019	0.029	0.004	0.032	0.003	0.067	12	None	N
DD	Low-Copper Pure Iron	A	" " "	0.019	0.028	0.004	0.027	0.004	0.028	18	None	N
OO	Low-Copper Open-hearth Steel	A	" " "	0.108	0.371	0.009	0.029	0.007	0.029	12	None	N
MM	Open-hearth Steel, Alan Wood Iron and Steel Co.	B	" " "	0.017	0.414	0.010	0.029	0.007	0.057	14	None	N
SS	Low-Copper Pure Iron, American Rolling Mill Co.	B	" " "	0.017	0.021	0.006	0.021	0.006	0.025	14	None	N
XX	Low-Copper Pure Iron, Inland Steel Co.	B	" " "	0.021	0.062	0.008	0.030	0.005	0.028	14	None	N
YY	Low-Copper Wrought Iron, Youngstown Sheet and Tube Co.	B	" " "	0.03	0.051	0.123	0.019	0.203	0.023	3	None	N
ZZ	Bessemer Steel, Youngstown Sheet and Tube Co.	B	" " "	0.07	0.40	0.097	0.037	0.008	0.013	3	None	N
ZZ	Open-hearth Steel, Youngstown Sheet and Tube Co.	B	" " "	0.032	0.40	0.044	0.028	.....	0.028	2	None	N
	Total	.....	.....	.....	.....	.....	.....	.....	.....	126	None	N
											No. 22 GAGE	SHEET
B	Open-hearth Steel	A	Copper-Bearing	0.06	0.27	0.014	0.053	0.006	0.179	9	None	No
C	Copper-Bearing Pure Iron	A	" "	0.015	0.028	0.006	0.036	0.003	0.190	9	None	No
E	Puddled Iron	A	" "	0.033	0.034	0.114	0.021	0.134	0.283	12	None	No
H	Copper-Bearing Basic Open-hearth Steel	A	" "	0.069	0.387	0.016	0.027	0.004	0.244	12	None	No
I	Copper-Bearing Bessemer Steel	A	" "	0.041	0.365	0.097	0.068	0.008	0.252	18	None	No
K	Copper-Bearing Acid Open-hearth Steel	A	" "	0.107	0.447	0.091	0.046	0.004	0.237	16	None	No
M	Open-hearth Steel, Alan Wood Iron and Steel Co.	B	" "	0.093	0.419	0.013	0.041	0.011	0.185	14	None	No
T	Copper-Bearing Steel, Newport Rolling Mill Co.	B	" "	0.083	0.313	0.009	0.020	0.005	0.227	14	None	No
U	Copper-Bearing Pure Iron, Allegheny Steel Co.	B	" "	0.017	0.074	0.008	0.027	0.005	0.260	14	None	No
V	Copper-Bearing Pure Iron, Whitaker-Glessner Co.	B	" "	0.018	0.051	0.007	0.021	0.005	0.304	14	None	No
Z	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co.	B	" "	0.039	0.37	0.084	0.038	0.007	0.257	3	None	No
Z	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co.	B	" "	0.043	0.37	0.100	0.045	.....	0.533	2	None	No
Z	Copper-Bearing Open-hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.06	0.35	0.049	0.059	.....	0.212	3	None	No
Z	Copper-Bearing Open-hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.07	0.39	0.059	0.058	.....	0.268	3	None	No
Z	Copper-Bearing Open-hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.07	0.41	0.050	0.050	.....	0.621	3	None	No
	Total	.....	.....	.....	.....	.....	.....	.....	.....	146	None	No
A	Bessemer Steel	A	Non-Copper-Bearing	0.038	0.386	0.089	0.040	0.007	0.014	17	None	31, 32, 3 36, 37. 3 42, 43, 4 47 (
B	Open-hearth Steel	A	" " "	0.09	0.38	0.017	0.062	0.036	0.082	4	None	No
C	Copper-Bearing Pure Iron	A	" " "	0.01	0.028	0.002	0.027	0.002	0.139	2	None	No
D	Low-Copper Pure Iron	A	" " "	0.02	0.026	0.004	0.022	0.002	0.024	9	None	No
O	Low-Copper Open-hearth Steel	A	" " "	0.121	0.536	0.008	0.030	0.249	0.020	12	None	25, 26, 2 30, 31, 3 35, 36
S	Low-Copper Pure Iron, American Rolling Mill Co.	B	" " "	0.02	0.023	0.006	0.022	0.004	0.022	14	None.	35
X	Low-Copper Pure Iron, Inland Steel Co.	B	" " "	0.021	0.055	0.007	0.031	0.004	0.027	14	None	No
Y	Low-Copper Wrought Iron, Youngstown Sheet and Tube Co.	B	" " "	0.03	0.055	0.139	0.021	0.218	0.020	3	None	No
Z	Bessemer Steel, Youngstown Sheet and Tube Co.	B	" " "	0.055	0.37	0.119	0.048	0.003	0.013	3	None	11
Z	Bessemer Steel, Youngstown Sheet and Tube Co.	B	" " "	0.07	0.40	0.088	0.048	0.009	0.133	3	None	No
Z	Open-hearth Steel, Youngstown Sheet and Tube Co.	B	" " "	0.10	0.32	0.069	0.044	0.002	0.018	3	None	No
	Total	.....	.....	.....	.....	.....	.....	.....	.....	84	None	3

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[1] In preparing this table, sheets below 0.15 per cent copper have been considered as non-copper-bearing, and those above 0.15 per cent as copper-bearing.

[2] These "Y" Sheets were reported as failures at the Nov. 5, 1919, inspection, but are placed in this column because they were exposed about six months later than all other sheets.

PLATE II.
PROC. AM. SOC. TESTING MATS.
VOL. 28, PART I.
REPORT OF COMMITTEE A-5:
CORROSION TESTS.

3. SHEETS EXPOSED DECEMBER 12, 1916. COMPARING COPPER-BEARING WITH NON-COPPER-BEARING MATERIALS.[1]

Date of Inspection.											Number of sheets Failed in Test.
April 9, 1918. 16 Months.	Oct. 7, 1918. 22 Months.	April 1, 1919. 28 Months.	Nov. 5, 1919. 35 Months.	May 11, 1920. 41 Months.	Oct. 12, 1920. 46 Months.	April 5, 1921. 52 Months.	Oct. 18, 1921. 58 Months.	April 11, 1922. 64 Months.	Oct. 17, 1922. 70 Months.	Mar. 9, 1923. 75 Months.	
E SHEETS.											
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	25, 26, 27, 28, 29 30, 50, 51, 52, 53 54, 55, 56 (13)	21, 22, 23, 24 (4)	....	....	....	....	....	....	....	17 (All)
None	None	None	None	None	None	None	23 (1)	20, 21 (2)	24 (1)	None	4
None	None	None	None	None	None	None	18 (1)	15, 17 (2)	16, 31, 33 (3)	None	6
None	None	None	None	None	None	25, 26 (2)	27, 28, 29, 30, 31 54, 55, 57, 58 (9)	8, 9, 49 (3)	47, 48 (2)	56 (1)	17
None	None	None	None	None	27 (1)	25, 26, 28, 33 (4)	29, 30, 31, 34, 35 36 (6)	None	32 (1)	....	12 (All)
None	None	None	None	None	None	None	29, 30, 35, 38, 40 (5)	41 (1)	31, 32, 37, 39, 42 (5)	None	11
None	None	None	None	29, 30, 31, 32, 33 35, 39, 40 (8)	34, 36, 37, 38, 41 42 (6)	....	....	....	....	....	14 (All)
None	None	None	None	29, 30, 31, 32 41 (5)	36 (1)	33, 34, 35, 38 39, 40 (6)	7, 42 (2)	....	....	....	14 (All)
None	None	None	None	None	None	7, 9 (2)	8 (1)	....	....	....	3 (All)
None	None	None	8, 10, 14 (3)	....	....	....	....	....	....	....	3 (All)
None	None	None	None	None	None	None	None	None	427 (1)	None	1
None	None	13	7	13	8	14	25	8	13	1	102
SHEETS.											
None	None	None	17 (1)	18 (1)	21, 23 (2)	22, 34, 39 (3)	19, 20 (2)	....	....	....	9 (All)
None	None	None	11, 13, 14, 22 (4)	32, 34, 35 (3)	33 (1)	12 (1)	....	....	....	....	9 (All)
None	32, 36 (2)	29, 30, 31, 35 (4)	25, 27, 33, 34 (4)	26, 28 (2)	....	....	....	....	....	....	12 (All)
None	None	None	None	None	None	38, 40, 42, 45, 49 50, 53, 54, 55 (9)	47 (1)	43 (1)	41 (1)	....	12 (All)
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	36, 41 (2)	37, 39 (2)	34, 42, 43, 45, 46 47, 48 (7)	None	11
None	None	None	None	32, 36, 42 (3)	39, 41 (2)	29, 30, 33, 34, 35 37, 38, 40 (8)	31 (1)	....	....	....	14 (All)
None	None	None	37, 39 (2)	32, 33, 35 36, 38 (5)	29, 30, 31, 34, 40 41, 42 (7)	....	....	....	....	....	14 (All)
None	None	None	41 (1)	29, 30, 40 (3)	31, 33, 34, 35, 38 42 (6)	32, 36, 37 39 (4)	....	....	....	....	14 (All)
None	None	None	29, 39 (2)	36, 37, 42 (3)	30, 33, 34, 35, 38 40, 41 (7)	31, 32 (2)	....	....	....	....	14 (All)
None	None	None	None	None	None	None	None	214 (1)	209, 213 (2)	....	3 (All)
None	None	None	None	None	None	None	None	None	310, 314 (2)	....	2 (All)
None	None	None	None	None	None	None	509, 513, 516 (3)	....	....	....	3 (All)
None	None	None	None	None	None	None	607, 608, 609 (3)	....	....	....	3 (All)
None	None	None	None	None	None	715 (1)	None	714 (1)	None	712 (1)	3 (All)
None	2	4	14	20	25	28	12	5	12	1	123
31, 32, 33, 34, 35 36, 37, 38, 40, 41 42, 43, 44, 45, 46 47 (16)	39 (1)	....	....	....	....	....	....	....	....	....	17 (All)
None	37 (1)	38 (1)	35 (1)	36 (1)	....	....	....	....	....	....	4 (All)
None	None	None	20 (1)	21 (1)	....	....	....	....	....	....	2 (All)
None	30, 36, 38 (3)	31, 33, 34, 35 39, 40 (6)	....	....	....	....	....	....	....	....	9 (All)
25, 26, 27, 28, 29 30, 31, 32, 33, 34 35, 36 (12)	....	....	....	....	....	....	....	....	....	....	12 (All)
35 (1)	29, 30, 31, 32, 33 34, 36, 37, 38, 39 40, 41, 42 (13)	....	....	....	....	....	....	....	....	....	14 (All)
None	29, 30, 31, 32, 33 34, 35, 36, 37, 38 39, 40, 41, 42 (14)	....	....	....	....	....	....	....	....	....	14 (All)
None	None	7, 8, 9 (3)[2]	....	....	....	....	....	....	....	....	3 (All)
11 (1)	6, 7 (2)	....	....	....	....	....	....	....	....	....	3 (All)
None	None	None	None	None	None	113 (1)	None	None	111, 112 (2)	....	3 (All)
None	422, 423, 424 (3)	....	....	....	....	....	....	....	....	....	3 (All)
30	37	10	2	2	None	1	None	None	2	....	84 (All)

TABLE VI.—FAILURES AT ANNAPOLIS TESTS. INSPECTIONS OF 1917, 1918, 1919, 1920, 1921, 1922
COMPARING COPPER-BEARING WITH NON-

Group	Designation	Series	Description	Average analysis, per cent						Number of Sheets in Test	
				Carbon	Man-ganese	Phos-phorus	Sulfur	Silicon	Copper		Mar. 5, 1923.[a] 77 Months
											No. 16 GAGE S
EE	Puddled Iron	A	Copper-Bearing	0.035	0.03	0.119	0.018	0.125	0.319	12	None
HH	Copper-Bearing Basic Open-hearth Steel	A	" "	0.074	0.373	0.011	0.026	0.004	0.237	16	None
II	Copper-Bearing Bessemer Steel	A	" "	0.059	0.371	0.095	0.066	0.006	0.247	16	None
KK	Copper-Bearing Acid Open-hearth Steel	A	" "	0.108	0.433	0.085	0.043	0.005	0.234	18	None
CCC	Copper-Bearing Pure Iron	A	" "	0.023	0.026	0.005	0.028	0.005	0.236	12	None
TT	Copper-Bearing Steel, Newport Rolling Mill Co	B	" "	0.080	0.313	0.009	0.020	0.006	0.223	14	None
UU	Copper-Bearing Pure Iron, Allegheny Steel Co	B	" "	0.018	0.066	0.008	0.028	0.005	0.239	14	None
VV	Copper-Bearing Pure Iron, Whitaker-Glessner Co	B	" "	0.018	0.046	0.007	0.019	0.004	0.299	14	None
ZZ	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co	B	" "	0.113	0.413	0.109	0.045	....	0.167	2	None
ZZ	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co	B	" "	0.080	0.34	0.091	0.036	....	0.293	3	None
ZZ	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co	B	" "	0.073	0.305	0.089	0.045	None	0.532	2	None
ZZ	Copper-Bearing Open-hearth Steel, Youngstown Sheet and Tube Co	B	" "	0.074	0.39	0.069	0.072	....	0.255	3	None
ZZ	Copper-Bearing Open-hearth Steel, Youngstown Sheet and Tube Co	B	" "	0.077	0.363	0.057	0.080	0.002	0.652	2	None
ZZ	Copper-Bearing Open-hearth Steel, Youngstown Sheet and Tube Co	B	" "	0.06	0.42	0.050	0.048	Trace	0.363	2	None
	Total			.....	.....	.....	.....	.....	....	130	None
AA	Bessemer Steel	A	Non-Copper-Bearing	0.043	0.419	0.083	0.042	0.004	0.012	18	None
BB	Open-hearth Steel	A	" " "	0.056	0.349	0.022	0.048	0.037	0.113	17	None
CC	Copper-Bearing Pure Iron	A	" " "	0.019	0.029	0.004	0.032	0.003	0.067	12	None
DD	Low-Copper Pure Iron	A	" " "	0.019	0.028	0.004	0.027	0.004	0.028	19	None
OO	Low-Copper Open-hearth Steel	A	" " "	0.108	0.371	0.009	0.029	0.007	0.029	12	None
MM	Open-hearth Steel, Alan Wood Iron and Steel Co	B	" " "	0.017	0.414	0.010	0.029	0.007	0.057	14	None
SS	Low-Copper Pure Iron, American Rolling Mill Co	B	" " "	0.017	0.021	0.006	0.021	0.006	0.025	14	None
XX	Low-Copper Pure Iron, Inland Steel Co	B	" " "	0.021	0.062	0.008	0.030	0.005	0.028	14	None
YY	Low-Copper Wrought Iron, Youngstown Sheet and Tube Co	B	" " "	0.03	0.051	0.123	0.019	0.203	0.023	3	None
ZZ	Bessemer Steel, Youngstown Sheet and Tube Co	B	" " "	0.08	0.43	0.080	0.031	0.008	0.014	3	None
ZZ	Open-hearth Steel, Youngstown Sheet and Tube Co	B	" " "	0.047	0.389	0.040	0.027	0.007	0.033	3	None
	Total			.....	.....	.....	.....	.....	.....	129	None
											No. 22 GAGE SH
B	Open-hearth Steel	A	Copper-Bearing	0.06	0.27	0.014	0.053	0.006	0.187	9	None
C	Copper-Bearing Pure Iron	A	" "	0.015	0.028	0.006	0.036	0.003	0.194	9	None
E	Puddled Iron	A	" "	0.033	0.034	0.114	0.021	0.134	0.283	11	None
H	Copper-Bearing Basic Open-hearth Steel	A	" "	0.069	0.387	0.016	0.027	0.004	0.244	16	None
I	Copper-Bearing Bessemer Steel	A	" "	0.041	0.365	0.097	0.068	0.008	0.252	16	None
K	Copper-Bearing Acid Open-hearth Steel	A	" "	0.107	0.447	0.091	0.046	0.004	0.237	16	None
M	Open-hearth Steel, Alan Wood Iron and Steel Co	B	" "	0.093	0.419	0.013	0.041	0.011	0.185	14	None
T	Copper-Bearing Steel, Newport Rolling Mill Co	B	" "	0.083	0.313	0.009	0.020	0.005	0.227	14	None
U	Copper-Bearing Pure Iron, Allegheny Steel Co	B	" "	0.017	0.074	0.008	0.037	0.005	0.260	14	None
V	Copper-Bearing Pure Iron, Whitaker-Glessner Co	B	" "	0.018	0.051	0.007	0.021	0.005	0.304	14	None
Z	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co	B	" "	0.058	0.37	0.093	0.043	0.009	0.269	3	None
Z	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co	B	" "	0.055	0.38	0.110	0.046		0.527	3	None
Z	Copper-Bearing Open-hearth Steel, Youngstown Sheet and Tube Co	B	" "	0.067	0.351	0.045	0.052	0.003	0.187	3	None
Z	Copper-Bearing Open-hearth Steel, Youngstown Sheet and Tube Co	B	" "	0.065	0.35	0.050	0.059	0.003	0.264	3	None
Z	Copper-Bearing Open-hearth Steel, Youngstown Sheet and Tube Co	B	" "	0.073	0.42	0.052	0.054	Trace	0.641	3	None
	Total			.....	.....	.....	.....	....	....	148	None
A	Bessemer Steel	A	Non-Copper-Bearing	0.038	0.386	0.089	0.040	0.007	0.014	14	None
B	Open-hearth Steel	A	" " "	0.09	0.38	0.017	0.062	0.036	0.084	3	None
C	Copper-Bearing Pure Iron	A	" " "	0.01	0.028	0.002	0.027	0.002	0.141	3	None
D	Low-Copper Pure Iron	A	" " "	0.02	0.026	0.004	0.022	0.002	0.024	7	None
O	Low-Copper Open-hearth Steel	A	" " "	0.121	0.536	0.008	0.030	0.249	0.020	12	None
S	Low-Copper Pure Iron, American Rolling Mill Co	B	" " "	0.02	0.023	0.006	0.022	0.004	0.022	14	None
X	Low-Copper Pure Iron, Inland Steel Co.	B	" " "	0.021	0.055	0.007	0.031	0.004	0.027	14	None
Y	Low-Copper Wrought Iron, Youngstown Sheet and Tube Co	B	" " "	0.03	0.055	0.139	0.021	0.218	0.020	3	None
Z	Bessemer Steel, Youngstown Sheet and Tube Co	B	" " "	0.063	0.41	0.102	0.044	0.009	0.013	3	None
Z	Bessemer Steel, Youngstown Sheet and Tube Co	B	" " "	0.077	0.44	0.095	0.036	0.003	0.140	3	None
Z	Open-hearth Steel, Youngstown Sheet and Tube Co	B	" " "	0.032	0.32	0.063	0.042	.....	0.019	3	None
	Total			.....	.....	.....	.....	.....	.....	79	None

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[1] In preparing this table, sheets below 0.15 per cent copper have been considered as non-copper-bearing, and those above 0.15 per cent copper as copper-bearing.

[a] No failures were recorded at inspections made prior to March 5, 1923; the detail records are accordingly not given here.

PLATE III.
PROC. AM. SOC. TESTING MATS.
VOL. 28. PART I.
REPORT OF COMMITTEE A-5:
CORROSION TESTS.

, 1922,[a] 1923, 1924, 1925, 1926, 1927, AND MAY, 1928. SHEETS EXPOSED OCTOBER 17, 1916.
NON-COPPER-BEARING MATERIALS.[1]

	Date of Inspection										Number of Sheets Failed in Test
, 1923.[a] onths	Oct. 10, 1923. 84 Months	Apr. 18, 1924. 90 Months	Oct. 23, 1924. 96 Months	Mar. 27, 1925. 101 Months	Oct. 10, 1925. 108 Months	Mar. 29, 1926. 113 Months	Nov. 17, 1926. 121 Months	Mar. 21, 1927. 125 Months	Oct. 5, 1927. 132 Months	May 7, 1928. 139 Months	
GAGE SHEETS											
one	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None
ne	None	None	None	None	None	None	None	None	None	None	None
ne	None	None	None	None	None	None	None	None	None	None	None
ne	None	None	None	None	None	None	None	None	None	None	None
ne	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None
GAGE SHEETS											
one	None	None	None	4 (1)	None	None	None	None	None	None	1
one	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	1	None	None	None	None	None	None	1
one	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None
one	1 (1)	None	None	None	3, 4, 5, 9 (4)	2 (1)	6, 11 (2)	None	7, 10 (2)	None	10
one	5 (1)	None	7 (1)	8 (1)	4 (1)	14 (1)	3 (1)	None	13 (1)	6, 11 (2)	9
one	None	None	None	None	None	None	None	4 (1)	None	None	1
one	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	1, 2, 3 (3)	3 (all)
one	None	None	None	None	None	None	None	None	None	None	None
one	None	None	None	None	None	None	None	None	None	None	None
one	2	None	1	1	5	2	3	1	3	5	23

for the various types of metals, together with average compositions, for the No. 22 gage sheets at the Fort Sheridan location. Groups rated as "first" have shown no failures in the 132 months of the tests. Groups rated as "second" have shown failures mainly within the past year after 119 months exposure. The group rated as "third" has shown an increasing number of failures over the preceding groups during the past year, and so on in the rating in the order of earlier and increasing numbers of failures to the end of the table.

TABLE III.—SUMMARY INDICATING ORDER OF RESISTANCE TO CORROSION UNDER ATMOSPHERIC EXPOSURE, FORT SHERIDAN TESTS.

Rating	Group	Type Description[a]	Average Analysis, per cent					
			Carbon	Manganese	Phosphorus	Sulfur	Silicon	Copper
First	Average H Sheets	Copper-Bearing Basic Open-hearth Steel	0.069	0.387	0.016	0.027	0.004	0.244
	Average I Sheets	Copper-Bearing Bessemer Steel	0.041	0.365	0.097	0.068	0.008	0.252
	Average K Sheets	Copper-Bearing Acid Open-hearth Steel	0.107	0.447	0.091	0.046	0.004	0.237
	Average Z-109, 110	Non-Copper Bessemer Steel	0.06	0.38	0.077	0.035	0.009	0.130
	Average Z-207, 208	Copper-Bearing Bessemer Steel	0.06	0.37	0.094	0.038	0.007	0.263
	Average Z-306, 308	Copper-Bearing Bessemer Steel	0.05	0.37	0.114	0.048	.....	0.533
	Average Z-506, 508	Copper-Bearing Open-hearth Steel	0.06	0.35	0.049	0.059	.....	0.212
	Average Z-605, 606	Copper-Bearing Open-hearth Steel	0.06	0.39	0.047	0.047	.....	0.286
	Average Z-709, 710	Copper-Bearing Open-hearth Steel	0.07	0.41	0.042	0.042	.....	0.532
Second	Average E Sheets	Copper-Bearing Wrought Iron	0.033	0.034	0.114	0.021	0.134	0.283
	Average M, T, B Sheets	Copper-Bearing Open-hearth Steel	0.079	0.334	0.012	0.038	0.007	0.189
Third	Average C, U, V Sheets	Copper-Bearing Pure Iron	0.016	0.051	0.006	0.030	0.004	0.245
Fourth	Average D, S, X Sheets	Non-Copper Pure Iron	0.021	0.035	0.006	0.025	0.003	0.024
Fifth	Average Y-4, 5, 6	Non-Copper Wrought Iron	0.03	0.055	0.139	0.201	0.218	0.020
Sixth	Average A Sheets, Z-4, 5	Non-Copper Bessemer Steel	0.054	0.413	0.098	0.043	0.005	0.012
Seventh	Average Z-420, 421	Non-Copper Open-hearth Steel	0.06	0.32	0.065	0.044	0.002	0.018
Eighth	Average O Sheets	Non-Copper Open-hearth Steel	0.121	0.536	0.008	0.030	0.249	0.020

[a] Copper-Bearing indicates copper content 0.15 per cent or over. Non-Copper indicates copper content less than 0.15 per cent.

As a convenience for ready comparison the following ratings for the No. 22 gage sheets at the Pittsburgh location (at the time this test was discontinued on March 8, 1923), as shown in the report of Committee A-5 in 1923,[1] are given, the most resistant groups being given first.

Rating	Group	Type Description[a]	Average Analysis, per cent					
			Carbon	Manganese	Phosphorus	Sulfur	Silicon	Copper
First	Average I Sheets	Copper-Bearing Bessemer Steel	0.041	0.365	0.097	0.068	0.008	0.252
Second	Average K Sheets	Copper-Bearing Acid Open-hearth Steel	0.107	0.447	0.091	0.046	0.004	0.237
Third	Average H Sheets	Copper-Bearing Basic Open-hearth Steel	0.069	0.387	0.016	0.027	0.004	0.244
Fourth	Average C, U, V Sheets	Copper-Bearing Pure Iron	0.016	0.051	0.007	0.031	0.004	0.251
Fifth	Average E Sheets	Copper-Bearing Wrought Iron	0.033	0.034	0.114	0.021	0.134	0.283
Sixth	Average Y Sheets	Non-Copper Wrought Iron	0.03	0.055	0.139	0.021	0.218	0.020
Seventh	Average D, S, X Sheets	Non-Copper Pure Iron	0.02	0.035	0.006	0.025	0.003	0.024
Eighth	Average Z 422, 423, 424	Non-Copper Basic Open-hearth Steel	0.10	0.32	0.069	0.044	0.002	0.018
Ninth	Average A Sheets	Non-Copper Bessemer Steel	0.038	0.386	0.089	0.040	0.007	0.014
	Average Z-6, 7, 11		0.055	0.37	0.119	0.048	0.003	0.013

[a] Copper-Bearing indicates copper content 0.15 per cent or over. Non-Copper indicates copper content less than 0.15 per cent.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 151 (1923).

Table IV is presented as showing in condensed form the composition of groups of sheets that have completely failed at the Fort Sheridan location at the abandonment of the test April 16, 1928.

The sheets at Annapolis, Md., were inspected on May 7, 1928, by Messrs. Gibboney, McAdam, Passano, Smith, Taylerson and Wheaton; Messrs. Fleming and McDonnell being absent. The following additional failures were recorded:

Sheet S-6 (No. 22 gage Low-Copper Pure Iron, Series B), manufactured by the American Rolling Mill Co., failed due to long transverse crack about midway the length of the sheet.

TABLE IV.—AVERAGE COMPOSITION OF GROUPS OF SHEETS OF FORT SHERIDAN TESTS THAT HAVE COMPLETELY FAILED.

Sheets Exposed April 9, 1917.

Group	Type Designation	Average Analysis, per cent					
		Carbon	Manganese	Phosphorus	Sulfur	Silicon	Copper
A-16 to 30	No. 22 gage Low-Copper Bessemer Steel, Series A	0.038	0.386	0.089	0.040	0.007	0.014
C-6, 7, 8, 9, 10, 27, 28, 29, 30, 31	Copper-Bearing Pure Iron, Series A	0.015	0.028	0.006	0.036	0.003	0.195
C-18, 19	Copper-Bearing Pure Iron, Series A	0.01	0.028	0.002	0.027	0.002	0.144
D-16, 18, 22, 24, 25, 28	No. 22 gage Low-Copper Pure Iron, Series A	0.02	0.026	0.004	0.022	0.002	0.024
O-13 to 24	No. 22 gage Low-Copper Open-hearth Steel. Series A	0.121	0.536	0.008	0.030	0.249	0.020
S-15 to 28	No. 22 gage Low-Copper Pure Iron, Series B, American Rolling Mill Co	0.02	0.023	0.006	0.022	0.004	0.022
U-15 to 28	No. 22 gage Copper-Bearing Pure Iron, Series B, Allegheny Steel Co	0.017	0.074	0.008	0.037	0.005	0.260
V-15 to 28	No. 22 gage Copper-Bearing Pure Iron, Series B, Whitaker-Glessner Co	0.018	0.051	0.007	0.021	0.005	0.304
Y-4, 5, 6	Low-Copper Wrought Iron, Series B, Youngstown Sheet and Tube Co	0.03	0.055	0.139	0.021	0.218	0.020
Z-4, 5	No. 22 gage Low-Copper Bessemer Steel, Series B, Youngstown Sheet and Tube Co	0.07	0.44	0.107	0.046	0.003	0.011
Z-420, 421	No. 22 gage Low-Copper Open-hearth Steel, Series B, Youngstown Sheet and Tube Co	0.06	0.32	0.065	0.044	0.002	0.018

Sheet S-11 (No. 22 gage Low-Copper Pure Iron, Series B), manufactured by the American Rolling Mill Co., failed due to a small hole near the bottom of the sheet.

Sheets Z-1, 2 and 3 (No. 22 gage Low-Copper Bessemer Steel, Series B) ,manufactured by the Youngstown Sheet and Tube Co., failed due to small holes near the bottom of the sheets.

No detailed record regarding texture, color and adherence of rust, or photographs of failures were made at this inspection; however, all mechanical damage not previously noted was recorded by the inspectors.

Table VI, Plate III, is presented as a continuation of the same general plan of grouping the sheets at Annapolis as regarding the presence of copper and recording the failures at all inspection periods.

Table V, Plate II, showing the failures at the Pittsburgh location when abandoned in March, 1923, is reproduced at this time for convenient comparison with the Fort Sheridan and Annapolis results.

The discontinuation of the Pittsburgh tests on March 9, 1923, and of the Fort Sheridan tests on April 16, 1928, leaves the Annapolis test remaining for further study. The rate of corrosion continues slow at Annapolis with very few additional failures during the past year.

At the close of eleven years' observations of these tests the sub-committee would direct attention to the fact that the failures at the Fort Sheridan location confirm the findings at the Pittsburgh location that copper-bearing metal shows marked superiority in rust resisting properties as compared to non-copper-bearing metal of substantially the same general composition under atmospheric exposure.

The election of a chairman for the ensuing term of two years resulted in the selection of the present incumbent.

This report was considered by the sub-committee at its meeting at Annapolis on May 7, 1928, and was unanimously approved.

Respectfully submitted on behalf of the sub-committee,

J. H. GIBBONEY,
Chairman.

Washington Immersion Test:

The final results of the immersion tests on No. 16 gage sheets in city water at the U. S. Bureau of Standards, Washington, D. C., are reported in detail in Table I (Plate IV).

TABLE II.—FINAL SUMMARY OF IMMERSION TESTS ON NO. 22 AND NO. 16 GAGE SHEETS IN WASHINGTON, D. C., CITY WATER AT THE U. S. BUREAU OF STANDARDS.

(For details of No. 16 gage specimens see Table I).

Class of Material	No. 22 Gage		No. 16 Gage	
	Number of Samples	Average Life in Days	Number of Samples	Average Life in Days
Non-Copper-Bearing Bessemer Steel	18	899.1	12	1932.8
Copper-Bearing Bessemer Steel	18	880.1	24	1858.5
Non-Copper-Bearing Basic Open-Hearth Steel	18	874.8	24	1908
Copper-Bearing Basic Open-Hearth Steel	36	863.8	30	1963
Non-Copper-Bearing Pure Iron	18	899.7	24	2049
Copper-Bearing Pure Iron	18	967.6	18	2074
Copper-Bearing Acid Open-Hearth Steel	6	821.8	6	1858.5
Non-Copper-Bearing Puddled Iron	6	740.5	6	1747.1
Copper-Bearing Puddled Iron	6	791.5	6	2028

TABLE III.—AVERAGE MONTHLY TEMPERATURES AND FIELD ANALYSES OF WASHINGTON CITY WATER AND SEVERN RIVER WATER AT ANNAPOLIS, MD.

Month	Temperature, deg. Cent.		Alkalinity in Terms of Calcium Carbonate, p.p.m.		Dissolved Oxygen, c.c. per liter		pH	
	Washington	Annapolis	Washington	Annapolis	Washington	Annapolis	Washington	Annapolis
January	6.3	2.5	56	59	8.0	7.5	7.2	7.6
February	6.5	5.0	40	49	7.4	5.6	7.2	7.5
March	10.0	8.2	39	50	6.9	5.3	7.3	7.6
April	15.7	11.7	46	37	5.6	5.0	7.1	7.2
May	20.7	17.2	59	55	5.5	4.9	7.3	7.3
June	24.7	20.8	59	61	4.0	5.1	7.2	7.3
July	27.6	25.7	66	62	3.5	3.1	7.4	7.5
August	27.6	24.8	74	61	3.2	3.6	7.4	7.5
September	25.3	23.7	77	68	4.0	4.5	7.3	7.5
October	18.2	16.7	73	65	4.7	4.4	7.5	7.7
November	13.1	12.1	73	69	5.7	5.6	7.3	7.8
December	9.7	7.2	74	59	6.3	5.4	7.4	7.6
Average	17.1	14.6	61	57	5.4	5.0	7.3	7.5

The average life of the various classes of material exposed is summarized in Table II, including the No. 22 gage specimens of the same sheets previously reported.[1] It will be noted that the No. 16 gage sheets (which are double the thickness of the No. 22 gage sheets) lasted a little more than twice as long.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 24, Part I, p. 228 (1924).

TABLE I.—FINAL REPORT ON SUBMERGED TESTS. SHEETS EXPOSED

Group	Designation	Series	Description	Average Analysis, per cent						Number of Sheets in Test	Jan. 24, 1924, 1261 Days	Aug. 14, 1924,
				Carbon	Manganese	Phosphorus	Sulfur	Silicon	Copper			
AA	Bessemer Steel	A	Non-Copper-Bearing	0.053	0.428	0.088	0.042		0.009	6		
ZZ	Bessemer Steel, Youngstown Sheet and Tube Co	B	" " "	0.076	0.385	0.096	0.037		0.012	6		
II	Copper-Bearing Bessemer Steel	A	Copper-Bearing	0.055	0.381	0.099	0.066		0.236	6		
ZZ1	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co	B	" "	0.080	0.400	0.091	0.035	0.056	0.154	6		
ZZ2	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co	B	" "	0.088	0.306	0.089	0.046		0.271	6		2
ZZ3	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co	B	" "	0.066	0.363	0.085	0.033		0.548	6		
OO	Basic Open-Hearth Steel	A	Non-Copper-Bearing	0.116	0.378	0.010	0.026	0.005	0.030	6	35	
MM	Basic Open-Hearth Steel, Alan Wood Iron and Steel Co	B	" " "	0.101	0.426	0.009	0.032		0.048	6		
ZZ4	Basic Open-Hearth Steel, Youngstown Sheet and Tube Co	B	" " "	0.029	0.395	0.044	0.026		0.029	6		4
BB	Basic Open-Hearth Steel	A	" " "	0.043	0.316	0.033	0.062	0.097	0.126	6		
HH	Copper-Bearing Basic Open-Hearth Steel	A	Copper-Bearing	0.085	0.391	0.013	0.025		0.230	6		
TT	Copper-Bearing Basic Open-Hearth Steel, Newport Rolling Mill Co	B	" "	0.078	0.301	0.008	0.021		0.215	6		
ZZ5	Copper-Bearing Basic Open-Hearth Steel, Youngstown Sheet and Tube Co	B	" "	0.065	0.367	0.053	0.064		0.223	6		
ZZ6	Copper-Bearing Basic Open-Hearth Steel, Youngstown Sheet and Tube Co	B	" "	0.090	0.330	0.034	0.055		0.574	6		
ZZ7	Copper-Bearing Basic Open-Hearth Steel, Youngstown Sheet and Tube Co	B	" "	0.063	0.391	0.052	0.045		0.355	6		
CC	Low-Copper Pure Iron	A	Non-Copper-Bearing	0.021	0.033	0.004	0.031		0.060	6		
DD	Low-Copper Pure Iron	A	" " "	0.021	0.029	0.004	0.025		0.025	6		
SS	Pure Iron, American Rolling Mill Co	B	" " "	0.014	0.018	0.006	0.024		0.027	6		
XX	Pure Iron, Inland Steel Co	B	" " "	0.026	0.054	0.008	0.026		0.029	6		
CCC	Copper-Bearing Pure Iron	A	Copper-Bearing	0.016	0.026	0.005	0.026	0.005	0.220	6		
UU	Copper-Bearing Pure Iron, Allegheny Steel Co	B	" "	0.016	0.065	0.009	0.030		0.244	6		
VV	Copper-Bearing Pure Iron, Whitaker-Glessner Co	B	" "	0.017	0.039	0.007	0.021		0.290	6		
KK	Copper-Bearing Acid Open-Hearth Steel	A	Copper-Bearing	0.118	0.408	0.081	0.043		0.229	6		
YY	Low-Copper Puddled Iron, Youngstown Sheet and Tube Co	B	Non-Copper-Bearing	0.030	0.060	0.124	0.018	0.216	0.024	6		
EE	Copper-Bearing Puddled Iron	A	Copper-Bearing	0.033	0.045	0.117	0.017	0.132	0.325	6		
										150	1	
	Total Failures to Date	...	...	...	...	...	...	...	...	...	1	

POSED AUGUST 10, 1920, IN RUNNING WASHINGTON CITY WATER AT THE U. S. BUREAU OF STANDARDS, WASHINGTON, D. C.

No. 16 GAGE SHEETS

	Failures on Date of Inspections																					
	Aug. 14, 1924, 1464 Days	Sept 20, 1924, 1501 Days	Nov 20, 1924, 1562 Days	Dec. 17, 1924, 1589 Days	Jan. 14, 1925, 1624 Days	Feb. 28, 1925, 1662 Days	Mar. 27, 1925, 1689 Days	Apr. 27, 1925, 1720 Days	June 4, 1925, 1758 Days	July 7, 1925, 1791 Days	Aug. 7, 1925, 1822 Days	Sept. 8, 1925, 1854 Days	Oct. 20, 1925, 1896 Days	Nov. 20, 1925, 1927 Days	Jan. 11, 1926, 1970 Days	Feb. 13, 1926, 2012 Days	Mar 17, 1926, 2044 Days	Apr. 19, 1926, 2077 Days	May 17, 1926 2105 Days	June 17, 1926 2136 Days	July 16, 1926, 2165 Days	Aug. 18, 1926, 2198 Days
	37						40 14, 14		52					43 7				49			8	8
	55 213	213			106	106 314, 314					45, 47 208		208 310	106	40, 50	106, 106 209 310	43 311	209	107 311			
5	422		427	426	39	36	34	42	31			422		37 422	31, 33 40	33 426		51	53	45	47, 48	
				39		510 615	715		36 507	46, 48 27	40 30, 33	42	44 714			714	615	37 510 713, 714	714	39 507, 509		612, 615
				11		25	36	16	57		12	33	24 42	50 34			27 38			42, 52 14, 13	40	
											33, 34, 28 37		26, 29 55	29, 30	35						32 40	
						57			52			45, 47			40		50					
			7			1		7	1			1		7								
								23			33				30	27			25			
1	4	1	2	3	2	9	6	4	7	3	12	6	9	10	8	8	6	7	5	8	6	3
1	5	6	8	11	13	22	28	32	39	42	54	60	69	79	87	95	101	108	113	121	127	130

I.—FINAL REPORT ON SUBMERGED TESTS. SHEETS EXPOSED AUGUST 10, 1920, IN RUNNING WASHINGTON CITY WATER AT THE U. S. BUREAU OF STANDARD

No. 16 GAGE SHEETS

tion	Average Analysis, per cent						Number of Sheets in Test	Failures on Date of Inspecti														
	Carbon	Manganese	Phosphorus	Sulfur	Silicon	Copper		Jan. 24, 1924, 1261 Days	Aug. 14, 1924, 1464 Days	Sept 20, 1924, 1501 Days	Nov 20, 1924, 1562 Days	Dec. 17, 1924, 1589 Days	Jan. 14, 1925, 1624 Days	Feb. 28, 1925, 1662 Days	Mar. 27, 1925, 1689 Days	Apr. 27, 1925, 1720 Days	June 4, 1925, 1758 Days	July 7, 1925, 1791 Days	Aug. 7, 1925, 1822 Days	Sept. 8, 1925, 1854 Days	Oct. 20, 1925, 1896 Days	Nov. 20, 1925, 1927 Days
-Bearing	0.053	0.428	0.088	0.042		0.009	6		37						40		52					43
..	0.076	0.385	0.096	0.037		0.012	6								14, 14							7
Bearing	0.055	0.381	0.099	0.066		0.236	6		55										45, 47			
..	0.080	0.400	0.091	0.035	0.056	0.154	6						106	106								106
..	0.088	0.306	0.089	0.046		0.271	6		213	213									208		208	
..	0.066	0.363	0.085	0.033		0.548	6							314, 314							310	
r-Bearing	0.116	0.378	0.010	0.026	0.005	0.030	6	35						36	34							
..	0.101	0.426	0.009	0.032		0.048	6						39			42	31					37
..	0.029	0.395	0.044	0.026		0.029	6		422		427	426								422		422
..	0.043	0.316	0.033	0.062	0.097	0.126	6															
Bearing	0.085	0.391	0.013	0.025		0.230	6					39						46, 48	40		44	
..	0.078	0.301	0.008	0.021		0.215	6										36	27	30, 33	42		
..	0.065	0.367	0.053	0.064		0.223	6							510			507					
..	0.090	0.330	0.034	0.055		0.574	6							615								
..	0.063	0.391	0.052	0.045		0.355	6								715						714	
r-Bearing	0.021	0.033	0.004	0.031		0.060	6							25	36					33	24	
..	0.021	0.029	0.004	0.025		0.025	6										57					50
..	0.014	0.018	0.006	0.024		0.027	6														42	34
..	0.026	0.054	0.008	0.026		0.029	6					11				16			12			
Bearing	0.016	0.026	0.005	0.026	0.005	0.220	6												33, 34, 28			29, 30
..	0.016	0.065	0.009	0.030		0.244	6												37		26, 29	
..	0.017	0.039	0.007	0.021		0.290	6														55	
Bearing	0.118	0.408	0.081	0.043		0.229	6							57			52			45, 47		
r-Bearing	0.030	0.060	0.124	0.018	0.216	0.024	6				7			1		7	1			1		7
Bearing	0.033	0.045	0.117	0.017	0.132	0.325	6									23			33			
							150	1	4	1	2	3	2	9	6	4	7	3	12	6	9	10
....	......	......	......	......	......	......	....	1	5	6	8	11	13	22	28	32	39	42	54	60	69	79

PLATE IV.
PROC. AM. SOC. TESTING MATS.
VOL. 28, PART I.
REPORT OF COMMITTEE A-5:
TOTAL IMMERSION TESTS.

ANDARDS, WASHINGTON, D. C.

f Inspections																			Average Life in Days	Group
Nov. 20, 1925, 1927 Days	Jan. 11, 1926, 1979 Days	Feb. 13, 1926, 2012 Days	Mar 17, 1926, 2044 Days	Apr. 19, 1926, 2077 Days	May 17, 1926 2105 Days	June 17, 1926 2136 Days	July 16, 1926, 2165 Days	Aug. 18, 1926, 2198 Days	Sept. 20, 1926, 2231 Days	Oct. 30, 1926, 2271 Days	Nov. 30, 1926, 2302 Days	Jan. 6, 1927, 2339 Days	Feb. 5, 1927, 2369 Days	Apr. 11, 1927, 2434 Days	May 16, 1927, 2469 Days.	July 15, 1927, 2529 Days	Dec. 19, 1927, 2686 Days	Jan. 19, 1928, 2717 Days		
43				49								46							1875	AA
7							8	8		8									1990	ZZ
	40, 50		43																1851	II
106		106, 106			107														1890	ZZ1
		209		209															1795	ZZ2
		310	311		311														1896	ZZ3
	31, 33																	32	1881	OO
37	40	33																	1836	MM
422		426																	1734	ZZ4
				51	53	45	47, 48							50					2180	BB
				37															1827	HH
						39													1863	TT
				510		507, 509						509							2018	ZZ5
			615					612, 615			614		614						2128	ZZ6
		714		713, 714	714														1976	ZZ7
			27								30								1908	CC
50						42, 52							45		47				2133	DD
34			38				40						37	30					2139	SS
						14, 13											15		2015	XX
, 30							32												1914	CCC
	35						40					32							2016	UU
									43		54		49	52		51			2293	VV
	40		50																1858	KK
7																			1747	YY
	30	27			25											22			2028	EE
10	8	8	6	7	5	8	6	3	1	1	3	3	4	3	1	2	1	1		
79	87	95	101	108	113	121	127	130	131	132	135	138	142	145	146	148	149	150		

TABLE V.—REPORT ON SUBMERGED TESTS. SHEETS EXPOSED JUNE 2, 1920, IN RUNNING SEV

No. 16 GAGE S

Group	Designation	Series	Description	Average Analysis, per cent						Number of Sheets in Test	Aug. 6, 1925, 1890 Days	Sept. 9, 1925, 1924 Days	Oct. 22, 1925, 1967 Days
				Carbon	Manganese	Phosphorus	Sulfur	Silicon	Copper				
AA	Bessemer Steel	A	Non-Copper-Bearing	0.036	0.428	0.084	0.042		0.011	6		1, 10	
ZZ	Bessemer Steel, Youngstown Sheet and Tube Co.	B	" " "	0.080	0.427	0.081	0.031	0.008	0.014	6	4	1	
II	Copper-Bearing Bessemer Steel	A	Copper-Bearing	0.062	0.353	0.093	0.065	0.006	0.255	6		1, 10	
ZZ1	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co.	B	" "	0.112	0.412	0.109	0.045		0.167	6	103, 102, 102	102	
ZZ2	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co.	B	" "	0.076	0.340	0.088	0.034		0.291	6	202	201	
ZZ3	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co.	B	" "	0.072	0.305	0.089	0.045		0.532	6		307	
OO	Basic Open-Hearth Steel	A	Non-Copper-Bearing	0.109	0.358	0.011	0.029		0.025	6	1, 3, 4, 6	7, 8	
MM	Basic Open-Hearth Steel, Alan Wood Iron and Steel Co.	B	" " "	0.110	0.420	0.008	0.027	0.010	0.063	6	2, 7, 15		
ZZ4	Basic Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	" " "	0.060	0.390	0.040	0.024		0.033	6	417, 418, 418, 418		
BB	Basic Open-Hearth Steel	A	" " "	0.046	0.296	0.025	0.058		0.138	6	3, 6, 9, 15		
HH	Copper-Bearing Basic Open-Hearth Steel	A	Copper-Bearing	0.083	0.369	0.011	0.026	0.002	0.252	6	2, 5, 12		
TT	Copper-Bearing Basic Open-Hearth Steel, Newport Rolling Mill Co.	B	" "	0.087	0.338	0.008	0.019		0.221	6	1, 6, 8, 9		
ZZ5	Copper-Bearing Basic Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.078	0.390	0.071	0.075		0.256	6	503	501	
ZZ6	Copper-Bearing Basic Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.079	0.359	0.055	0.080		0.651	6			
ZZ7	Copper-Bearing Basic Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.060	0.420	0.050	0.048		0.363	6			
CC	Low-Copper Pure Iron	A	Non-Copper-Bearing	0.022	0.031	0.005	0.031	0.003	0.086	6	7	3	
DD	Low-Copper Pure Iron	A	" " "	0.020	0.027	0.004	0.028	0.002	0.027	6	11, 15, 16	12, 13	
SS	Pure Iron, American Rolling Mill Co.	B	" " "	0.022	0.032	0.005	0.018	0.007	0.027	6	3, 9, 17		
XX	Pure Iron, Inland Steel Co.	B	" " "	0.028	0.079	0.009	0.029		0.034	6	3, 5, 7, 32, 35	2	
CCC	Copper-Bearing Pure Iron	A	Copper-Bearing	0.022	0.027	0.005	0.028	0.006	0.251	6	3, 4, 12, 15		
UU	Copper-Bearing Pure Iron, Allegheny Steel Co.	B	" "	0.028	0.071	0.006	0.031	0.006	0.247	6	4, 6, 7, 8		1
VV	Copper-Bearing Pure Iron, Whitaker-Glessner Co.	B	" "	0.024	0.051	0.006	0.017		0.308	6	1, 19, 30, 31, 32		
KK	Copper-Bearing Acid Open-Hearth Steel	A	Copper-Bearing	0.098	0.453	0.085	0.041		0.220	6	9, 12, 16	6	
YY	Low-Copper Puddled Iron, Youngstown Sheet and Tube Co.	B	Non-Copper-Bearing	0.030	0.050	0.127	0.018	0.197	0.024	6	8, 8, 8, 8	9	
EE	Copper-Bearing Puddled Iron	A	Copper-Bearing	0.045	0.026	0.114	0.019	0.117	0.300	6			
										150	60	17	1
	Total Failures to Date											77	78

PLATE V.
PROC. AM. SOC. TESTING MATS.
VOL. 28, PART I.
REPORT OF COMMITTEE A-5:
TOTAL IMMERSION TESTS.

Severn River Water at the Naval Engineering Experiment Station, Annapolis, Md.

Gage Sheets

1967 Days	Nov. 24, 1925, 2000 Days	Feb. 19, 1926, 2087 Days	Mar. 25, 1926, 2121 Days	Apr. 24, 1926, 2151 Days	May 24, 1926, 2181 Days	June 24, 1926, 2212 Days	July 28, 1926, 2246 Days	Aug. 27, 1926, 2276 Days	Sept. 28, 1926, 2308 Days	Nov. 4, 1926, 2345 Days	Dec. 4, 1926, 2378 Days	Jan. 12, 1927, 2414 Days	Feb. 12, 1927, 2445 Days	May 6, 1927, 2528 Days	June 16, 1927, 2569 Days	July 19, 1927, 2602 Days	Sept. 29, 1927, 2674 Days	Dec. 5, 1927 2741 Days	Jan. 7, 1928, 2774 Days	Feb. 11, 1928, 2809 Days
		2					2							1	4	13			4	
				202			103	103 306		9	204		307	201 303	15 306			307		
	417	5		1													417		11	
			503, 503	16	12			3				501		1, 4 710, 711	602			710		710
		5	6, 12	8 21			1			10				14						
1				21		8	3		13											
				3						7										
			9																	
				9												4		2		
1	1	3	5	8	1	1	4	3	1	3	1	1	1	8	4	2	1	3	2	1
78	79	82	87	95	96	97	101	104	105	108	109	110	111	119	123	125	126	129	131	132

Table III includes a record of temperature, alkalinity, pH value, and dissolved oxygen contents of the Washington city water (and Severn River water at Annapolis) during the period of the tests.

Table IV shows an average analysis of Washington city water furnished by C. J. Lauter, Chief Chemist of the Dalecarlia Filter Plant, Washington, D. C.

TABLE IV.—ANALYSIS OF FILTERED WASHINGTON CITY WATER.
Composite Sample Parts per Million.

Date	Residue on Evaporation	Loss on Ignition	Alkalinity, Methylorange	Hardness as $CaCO_3$	SiO_2	$Fe_2O_3Al_2O_3$	Ca	Mg	$KNaCl_2$	NO_2	NO_3	Cl_2	SO_4	pH Average
July, 1923	100	32	76	84	4.0	1.9	27.8	3.9	7.5	0	0.40	3.3	24.8	7.3
August	94	30	73	94	6.0	1.6	27.7	6.0	...	0	0.60	3.2	24.0	7.3
September	120	40	64	81	6.8	1.0	25.4	4.3	...	0	0.50	3.3	27.2	7.1
October	108	38	78	94	5.0	2.4	28.0	5.8	...	0	0.70	3.3	22.5	7.4
November	125	43	95	105	6.4	2.2	34.0	4.9	...	0	0.65	6.0	15.7	7.7
December	115	26	65	83	6.5	2.1	26.0	4.2	8.0	0	0.65	6.1	22.7	7.3
January, 1924	88	26	30	49	8.0	...	17.2	1.4	...	0	0.55	4.0	20.4	6.9
February	84	22	38	53	8.0	...	17.2	2.4	...	0	0.65	3.7	22.2	7.0
March	76	22	37	57	6.0	1.4	17.2	3.3	...	0	0.68	3.9	19.4	6.9
April	81	27	31	46	7.4	1.2	15.9	1.5	...	0	0.67	3.8	23.2	7.0
May	86	29	44	54	8.0	1.0	19.5	1.8	...	0	0.65	3.2	22.7	7.1
June	91	30	49	57	8.0	1.0	20.4	1.6	11.0	0	0.60	3.8	23.6	7.2
Yearly Average	98	30	57	71	6.7	1.5	23.0	3.4	8.8	0	0.61	4.0	22.3	7.17
July, 1924	109	38	8	70	6.6	2.0	24.1	2.5	...	0	0.60	3.9	24.7	7.2
August	123	46	80	88	...	2.8	28.0	4.1	...	0	0.70	5.1	18.6	7.5
September	136	50	93	103	6.0	2.0	33.2	4.8	...	0	0.64	5.5	....	7.6
October	138	45	77	82	5.0	1.0	28.0	2.9	11.0	0	0.78	4.8	21.2	7.4
November	120	47	89	88	5.2	0.8	30.0	3.1	...	0	0.70	5.2	22.7	7.6
December	122	45	78	83	7.6	0.6	28.4	3.1	...	0	0.61	5.9	14.3	7.5
January, 1925	114	45	69	73	7.6	0.8	26.0	1.9	...	0	0.68	4.6	15.2	7.4
February	94	32	44	54	5.4	1.0	19.6	1.3	...	0	0.66	3.6	17.0	7.1
March	102	44	46	51	6.0	2.6	18.5	1.4	...	0	0.61	3.9	20.7	7.2
April	100	45	47	54	7.6	1.2	20.0	1.1	...	0	0.68	4.6	21.4	7.3
May	104	45	49	54	6.4	1.0	19.6	1.3	...	0	0.63	4.2	22.2	7.3
June	112	42	67	81	6.0	2.0	25.2	4.3	...	0	0.60	4.9	24.4	7.3
Yearly Average	113	44	67	73	6.3	1.5	25.0	2.7	...	0	0.65	4.7	20.2	7.3
July, 1925	154	65	74	83	7.0	1.0	28.8	2.6	...	0	0.61	5.4	21.0	7.32
August	138	56	76	85	3.0	1.2	29.2	3.1	...	0	0.58	5.4	22.0	7.44
September	138	49	80	89	5.4	1.2	30.0	3.5	...	0	0.58	4.9	16.4	7.4
October	149	60	80	93	6.2	1.0	30.0	4.2	...	0	0.55	5.2	22.4	7.5
November	136	46	47	68	8.0	1.2	24.0	1.9	...	0	0.65	4.2	21.0	7.2
December	110	42	48	58	6.0	1.2	20.0	2.1	...	0	0.64	4.2	19.0	7.3
January, 1926	128	52	59	72	6.8	1.4	24.0	3.1	...	0	0.66	4.0	21.0	7.35
February	100	40	30	44	6.0	1.4	16.0	1.1	..	0	0.61	4.8	24.0	6.87
March	83	23	29	44	5.0	1.8	16.0	1.1	...	0	0.62	4.2	20.4	7.0
April	94	36	42	56	6.0	1.0	18.4	2.6	...	0	0.75	4.6	19.8	7.2
May	102	22	63	72	7.2	1.4	24.0	3.0	...	0	0.75	5.0	14.0	7.4
June	125	45	75	83	5.0	2.0	28.4	2.8	11.8	0	0.73	5.2	17.0	7.4
Yearly Average	121	45	59	71	6.0	1.2	24.1	2.6	...	0	0.65	4.8	19.8	7.29
Maximum	154	65	95	105	8.0	2.8	34.0	5.8	11.8	0	0.78	6.1	27.2	7.7
Minimum	76	22	29	44	3.0	0.6	15.9	1.1	7.5	0	0.40	3.2	14.0	6.87
Three Year Average	111	39	61	72	6.3	1.4	24.0	2.9	10.5	0	0.64	4.5	20.7	7.25

Annapolis Immersion Tests:

Table V (Plate V) gives a detailed record of 132 failures out of 150 No. 16 gage specimens in the test in running Severn River water at the Naval Engineering Experiment Station, Annapolis, Md., up to February, 1928.

Table VI gives analyses made by T. P. Sager of the Bureau of Standards of typical samples of scale and rust taken from Washington and Annapolis test pieces which were unattacked on one side.

The longer life of the specimens exposed in brackish water at Annapolis compared with results with the same material in Washington city water may be due to the combined influence of a number of factors. Analysis of Annapolis water will be found in the report of the committee in 1924.[1] The greater amount of silica in both the scale and rust from Annapolis samples suggests that the Annapolis deposits are more protective. The average oxygen content and the temperatures are lower in Annapolis water; each of these factors tends to slow down the rate of corrosion.

TABLE VI.—ANALYSES OF SCALE.
(Calculated to Iron-Free Basis)

	Washington	Annapolis
Silica (SiO_2), per cent	0.71	1.44
Aluminum oxide (Al_2O_3), per cent	trace	0.11
Calcium oxide (CaO), per cent	52.69	52.54
Magnesium oxide (MgO), per cent	0.59	0.84
Sodium oxide (Na_2O), per cent	0.28	0.38
Potassium oxide (K_2O), per cent	trace	trace
Sulphur trioxide (SO_3), per cent	0.17	0.41
Chloride (Cl), per cent	0.04	0.09
Carbon dioxide (CO_2), per cent	42.01	41.92
Combined water and organic matter (loss on ignition less carbon dioxide), per cent	3.47	2.22
Note: The scale as removed from the plates contained iron oxide as follows:		
Ferric oxide (Fe_2O_3), per cent	7.66	14.21
Ferrous oxide (FeO), per cent	1.91	3.46

Sea Water Immersion Tests:

The No. 22 gage sheets exposed March 1, 1927, in sea water at Key West Navy Yard showed 6 failures on March 16, 1928. No failures have occurred up to this time in similar tests started March 7, 1927, at the Portsmouth Navy Yard.

The riveted plate and copper-bearing pipe immersed in sea water at Key West, Fla., Portsmouth, N. H., and Port Arthur, Tex., have been inspected regularly but so far no conclusions can be drawn. Details regarding installation of these tests will be found in the report of the sub-committee in 1927.[2]

The committee has changed the system of inspection of the riveted plate and pipe tests so that the specimens will hereafter be inspected every six months instead of every four months and the riveted plates will be cleaned by a light sand blast before inspection.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 24, Part I, p. 232 (1924).

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 183 (1927).

The election of a chairman for the ensuing term of two years resulted in the selection of the present incumbent.

Respectfully submitted on behalf of the sub-committee,

F. N. SPELLER,
Chairman.

REPORT OF SUB-COMMITTEE VI ON SPECIFICATIONS FOR ZINC-COATED PRODUCTS

During the year, the sub-committee prepared proposed Tentative Specifications for Zinc-Coated (Galvanized) Barb Wire, and for Zinc-Coated (Galvanized) Steel Wire Strand. The specifications are appended hereto[1] in their proposed form and are recommended for acceptance for publication as tentative.

Slight modifications in certain of the existing tentative specifications for wire products are being studied. Substantial progress has been made on specifications for zinc-coated wire rope highway guard, also one for chain-link highway guard. It is expected to complete these specifications for submission next year.

Some time ago samples were collected and an investigation on sherardized coatings was laid out. This rather difficult work has encountered unexpected delays due in part to changes in business connection of prominent participants. Plans are now developing to reorganize the work and it is hoped that definite progress will be made next year.

The election of a chairman for the ensuing term of two years resulted in the selection of F. F. Farnsworth.

Respectfully submitted on behalf of the sub-committee,

H. E. Smith,
Chairman.

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[1] See pp. 741 and 744, respectively.—Ed.

REPORT OF SUB-COMMITTEE VII ON METHODS OF TESTING

The work Sub-Committee VII is undertaking is largely of a research or fact-finding nature. Some work has been done along the lines planned and published in the report of Committee A-5 to the Society in 1927. The status of this work is reviewed below. Thus far, it has been confined to zinc-coated products.

Sub-Committee VII-A, Physical Tests of Coatings, W. H. Moore, chairman.—This committee is collecting samples of zinc-coated sheets to be used in studying the significance and usefulness of methods of physically testing coatings. Most of the samples thus far obtained have been supplied by a car roof manufacturer. The samples have been selected by observing their deportment in factory bending and forming operations and picking some sheets that have successfully withstood these operations without flaking and others that have flaked. The severity of the forming operation has been noted in each case. These selected samples will be used by the committee to test just what parallelism there is between fabricating deportment and deportment of the sheets in laboratory tests such as bending tests, crimping tests, cupping tests, and the like. The committee plans to collect sheet samples from other sources and also zinc-coated wire samples.

Sub-Committee VII-B, Quantitative Analysis of Coatings.—Jesse L. Jones has been appointed chairman of this sub-committee to succeed H. E. Brooks, who has resigned because of ill health. This committee has clarified its work by sending out a questionnaire, the returns of which determined the line of work now under way. This work is to amplify or modify in the following respects the Society's Standard Methods of Determining Weights of Coating on Zinc-Coated Articles (A 90 – 24):

1. The addition of the method of using sulfuric acid alone to determine total weight of coating. This will be an alternative method to that of the standard hydrochloric acid - antimony chloride stripping method.

2. The elimination of the basic-lead-acetate method as an alternative procedure for determining total weight of coating.

3. The addition of methods of analysis to determine the content in zinc coatings of impurities such as the following: aluminum, tin, lead and cadmium.

Sub-Committee VII-C, Other Characteristics of Coating, F. A. Hull, chairman.—This committee is working on corrosion testing methods. Two or three industrial concerns are constructing testing apparatus for conducting accelerated weathering tests similar to the New Jersey Zinc Co. test, that is, exposure of specimens to successive cycles of water spray and air charged with carbon dioxide and sulfur dioxide, which are corrosive gases of the atmosphere. The construction of this equipment and the accumulation of experience in its operation will require an additional year or more. When these testing facilities are available, the committee expects to use them for purpose of judging the usefulness and significance of quickly performable tests such as the Preece test, salt spray test, etc. Sub-Committee VII has agreed that an accelerated weathering test of this type is the best yardstick that will be available for some time for use in evaluating the quick inspection tests. The final method of judging the value of the inspection tests will be to submit companion zinc-coated samples to these tests and to outdoor tests. Samples like those on the outdoor test racks of Sub-Committee VIII have been saved for this purpose.

The election for the ensuing term of two years resulted in the selection of the present incumbent.

Respectfully submitted on behalf of the sub-committee,

C. D. HOCKER,
Chairman.

REPORT OF SUB-COMMITTEE VIII ON FIELD TESTS OF METALLIC COATINGS

Sub-Committee VIII has held two well attended meetings during the past year, and its Section on Inspection of Galvanized Sheets has inspected the tests at all five locations twice during the year. The collection of the specimens of coated wire, fencing, conduit, pipe, bolts, hardware and fittings, roofing nails and wood screws, and structural shapes is progressing in a very satisfactory way. It is anticipated that these materials will be placed on the test racks this fall.

The work of the sub-committee continues to attract widespread interest and with the completion of the installation of the galvanized tests, the sub-committee expects to take up without delay the collection of specimens for the testing of other coatings, such as lead, chromium and cadmium.

The report of the Inspection Committee on Galvanized Sheets under the chairmanship of M. E. McDonnell, Chief Chemist, Pennsylvania Railroad, unanimously approved by the members, is included herewith.

REPORT ON INSPECTION OF GALVANIZED SHEETS

The galvanized sheets and bend tests on exposure at the five different test racks have been inspected twice during the year. The dates of inspections and members present were as follows:

ALTOONA, PA.

September 28, 1927:

A. C. Badger (representing G. A. Reinhardt)
J. H. Gibboney
R. F. Passano (representing W. J. Beck)
H. E. Smith
E. S. Taylerson

May 1, 1928:

R. L. Duff
C. D. Hocker
H. S. Rawdon
H. E. Smith
E. S. Taylerson
C. S. Trewin
F. A. Weidman
M. E. McDonnell

BRUNOT ISLAND (PITTSBURGH), PA.

September 27, 1927:

W. C. Carroll
J. H. Gibboney
R. F. Passano (representing W. J. Beck)
G. A. Reinhardt
H. E. Smith
E. S. Taylerson
R. H. Dibble, American Sheet and Tin Plate Co. (visitor)
Max Hecht, Duquesne Light Co. (visitor)

April 30, 1928:

- A. C. Badger (representing G. A. Reinhardt)
- R. L. Duff
- C. D. Hocker
- H. S. Rawdon
- H. E. Smith
- E. S. Taylerson
- C. S. Trewin
- M. E. McDonnell
- G. N. Schramm, American Sheet and Tin Plate Co. (visitor)

SANDY HOOK, N. J.

October 7, 1927:

- R. L. Duff
- R. F. Passano (representing W. J. Beck)
- E. S. Taylerson
- C. S. Trewin
- F. A. Weidman

May 3, 1928:

- R. L. Duff
- C. D. Hocker
- R. F. Passano (representing W. J. Beck)
- H. S. Rawdon
- H. E. Smith
- E. S. Taylerson
- C. S. Trewin
- F. A. Weidman
- M. E. McDonnell
- C. A. Giblin, Diamond Expansion Bolt Co. (visitor)
- H. W. Pleister, Diamond Expansion Bolt Co. (visitor)

KEY WEST, FLA.

October 11 to 13, 1927:

- C. D. Hocker
- E. S. Taylerson

March 15, 1928:

- J. W. Moody, Jr. (representing M. E. McDonnell)
- R. F. Passano (representing W. J. Beck)
- E. S. Taylerson
- H. R. Every, American Rolling Mill Co. (visitor)
- F. N. Speller, National Tube Co. (visitor)

STATE COLLEGE, PA.

September 29, 1927:

- A. C. Badger (representing G. A. Reinhardt)
- R. F. Passano (representing W. J. Beck)
- H. E. Smith
- E. S. Taylerson
- M. E. McDonnell
- E. D. Ries, Pennsylvania State College (visitor)

May 2, 1928:

- R. L. Duff
- C. D. Hocker
- R. F. Passano (representing W. J. Beck)
- H. S. Rawdon
- H. E. Smith
- E. S. Taylerson
- C. S. Trewin
- F. A. Weidman
- M. E. McDonnell
- W. H. Walker, consulting chemist (visitor)
- G. D. Wendt, Pennsylvania State College (visitor)

The results of these inspections may be summarized as follows:

Altoona, Pa.:

The galvanized sheets and bend tests on the Altoona test rack show more pronounced corrosion than any of the others. The test specimens have a dark colored appearance, due to a sooty deposit, which masks the earliest corrosion products, but does not mask the effect of more severe corrosion.

At the latest inspection, on May 1, 1928, all twelve No. 16 gage 2.50-oz., all eighteen No. 22 gage 2.50-oz., and all eighteen No. 22 gage 2-oz. zinc coated sheets were thoroughly protected by the coating, no yellowed oxide corrosion products being apparent and substantially no alloy layer was visible.

Some of the eighteen No. 22 gage 1.50-oz. coated sheets now show clear evidence of progressive corrosion. On the September 28, 1927, inspection no yellowed coating was reported by the participating inspectors, while on the May 1, 1928, inspection eleven of the eighteen showed yellowed corrosion products, and the presence of carbon rendered it difficult or impossible to differentiate between alloy layer and zinc coating.

The eighteen No. 22 gage 1.25-oz. coated sheets also now show marked evidence of progressive corrosion. On the September 28, 1927, inspection no visible yellowed corrosion products were reported. On the May 1, 1928, inspection the majority reported visible yellowed corrosion products on all eighteen sheets.

The fourteen No. 22 gage and ten No. 28 gage 0.75-oz. coated sheets now show pronounced evidence of progressive corrosion. On the inspection of September 28, 1927, six of the No. 22 gage 0.75-oz. and one of the No. 28 gage 0.75-oz. coated sheets were rated by the inspectors under the designation "R," indicating rusted, the remaining sheets being difficult to classify on account of the sooty deposit. On the inspection of May 1, 1928, seven of the fourteen No. 22 gage and four of the ten No. 28 gage 0.75-oz. coated sheets were corroded to a degree showing rough, reddish corrosion products, and they were consequently rated "R." The area of these rust spots varied from approximately $\frac{1}{2}$ sq. in. to 2 per cent of the total area of the sheet. All remaining sheets showed yellowed corrosion products.

The sheets were placed on the Altoona test rack on April 22, 1926, and the first indication of the destruction of the coating as shown by the formation of rough, reddish corrosion products was reported on the inspection of September 28, 1927, eighteen months and six days after the sheets had been exposed.

The following is a list of the Altoona sheets which have now been classified as "R," together with inspection dates:

September 28, 1927 (Time of exposure, 18 months and 6 days)	May 1, 1928 (Time of exposure, 24 months and 8 days)
No. 22 Gage, 0.75-oz.	No. 22 Gage, 0.75-oz.
VHC-[a]top	VHC-top
NHH-top	NHH-top
NHH-bottom	NHH-bottom
THK-top	THK-top
CHN-top	CHN-top
CHN-bottom	CHN-bottom
	SHE-top
No. 28 Gage, 0.75-oz.	No. 28 Gage, 0.75-oz.
YKH-top	YKH-top
	NKK-top
	TKA-top
	SKC-top

It was also noted on the inspection of May 1, 1928, that one black sheet on the Altoona test rack, designated YV-T, had failed, the failure consisting of cracks and one hole located over the bottom purlin.

Brunot Island (Pittsburgh), Pa.:

The galvanized sheets and bend tests on the Brunot Island test rack are slightly less corroded than the ones on the Altoona rack, although the difference is not very marked. The test specimens at Brunot Island have a dark colored appearance due to a sooty deposit, which masks the earliest corrosion products. All of the twelve No. 16 gage 2.50-oz., eighteen No. 22 gage 2.50-oz., and eighteen No. 22 gage 2-oz. zinc coated sheets are still thoroughly protected by the coating, no yellow corrosion products being apparent and substantially no alloy layer has as yet been exposed. All coatings on the above sheets are predominatingly zinc and have been graded "Z."

The eighteen No. 22 gage 1.50-oz. coated sheets did not show evidence of yellowed oxide coating on the inspection of September 27, 1927. On the inspection of April 30, 1928, eight of the eighteen sheets showed yellowed corrosion products, the remaining ten being zinc or alloy.

The eighteen No. 22 gage 1.25-oz. coated sheets did not show yellow corrosion products on the inspection of September 27, 1927.

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[a] For an explanation of the scheme of designation, see 1927 Report of Sub-Committee VIII, Committee A-5 on Corrosion of Iron and Steel, *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 191 (1927).

On the inspection of April 30, 1928, fourteen sheets showed yellowed corrosion products, the remaining four being zinc or alloy layer.

The fourteen No. 22 gage and ten No. 28 gage 0.75-oz. coated sheets now show pronounced evidence of progressive corrosion. On the inspection of September 27, 1927, six of the fourteen No. 22 gage and two of the ten No. 28 gage sheets showed yellowed corrosion products, the remaining sheets of both gages being zinc or alloy. On the inspection of April 30, 1928, five of the fourteen No. 22 gage sheets and two of the ten No. 28 gage sheets showed the formation of rough, reddish corrosion products, and were consequently rated "R." The remaining nine No. 22 gage and eight No. 28 gage sheets showed yellowed corrosion products and were rated "Y."

The Brunot Island sheets were exposed on April 21, 1926, and the first indication of the destruction of the zinc coating as indicated by the formation of rough, reddish corrosion products was found on the inspection of April 30, 1928, after an exposure of two years and nine days. The area of these spots on the different sheets so classified varied from approximately $\frac{1}{2}$ sq. in. to 2 per cent of the total area of the sheet.

The following is a list of the Brunot Island sheets which were classified as "R" on the inspection of April 30, 1928, after twenty-four months and nine days exposure:

No. 22 Gage, 0.75-oz.	No. 28 Gage, 0.75-oz.
VHH-top	TKE-top
NHK-top	YKK-top
NHK-bottom	
YHS-top	
CHM-top	

It was also noted on the inspection of April 30, 1928, that two black sheets on the Brunot Island test rack, designated RZ-T and YH-B, had failed. In the case of the RZ-T sheet the failure consisted in a hole approximately $\frac{1}{2}$ in. wide and 2 in. long near the middle, while the YH-B sheet contained two holes approximately $\frac{3}{4}$ to $1\frac{1}{2}$ in. in diameter over the bottom purlin and about 5 in. from the lower end of the sheet.

Sandy Hook, N. J.:

The sheets and bend tests on the Sandy Hook test rack show much less deterioration due to corrosion than the sheets exposed at Altoona and Brunot Island. The predominating coating is generally zinc on all of these sheets, except on some two of the lighter coated ones, on which the coating is now predominatingly alloy layer. In one instance a No. 22 gage sheet coated with 0.75 oz. of zinc shows a local yellowed spot.

Key West, Fla.:

The inspections at Key West on October 11 to 13, 1927, and on March 15, 1928, indicate that the sheets on this rack are being corroded less severely than at Brunot Island, Altoona and Sandy Hook. None of the galvanized sheets show any yellowed alloy layer, but some of the lighter coated sheets showed a small amount of gray alloy, generally in the chatter marks. A large portion of the sheets showed white incrustation, which was generally spotty rather than continuous, on the October, 1927, inspection, but which was more nearly continuous on the March 15, 1928, inspection. This coating obscured the metal coating underlying the white incrustation, rendering it difficult to detect the less prominent of the gray alloy layer markings known as chatter marks. The zinc coating was still intact, no yellow color due to corrosion of the alloy layer being visible. The rainfall at Key West was light prior to both of the above inspections.

The black sheets at this location appear to have a less adherent rust coating than at the other locations.

State College, Pa.:

The sheets and bend tests at State College show less deterioration than at any of the other test racks. All of the sheets are still protected by predominatingly zinc coating, and the sheets look clean and comparatively new.

The election of a chairman for the ensuing term of two years resulted in the selection of the present incumbent.

Respectfully submitted on behalf of the sub-committee,

F. A. HULL,
Chairman.

REPORT OF SUB-COMMITTEE IX ON METAL CULVERT CORROSION TESTS

Sub-Committee IX on Metal Culvert Corrosion Tests has held one meeting during the year. The work during the year has been directed largely towards the determination of source of information that may be available as the result of past or present investigations on the flexible metal culvert as an engineering material. The means for developing this information was through a questionnaire addressed to the state highway departments, the engineering departments of the railroads and other large consumers of culverts. The type of information desired is best revealed in a reading of the questionnaire given herewith:

Questionnaire

1. How long have corrugated metal culverts been in service in your state (or on your railroad)?

2. Has your experience with corrugated metal pipe culverts indicated a need for research on the variables affecting the durability of the material involved in their construction?

3. (*a*) Have you ever investigated the relative durability of corrugated metal pipe culverts as influenced by variations in type of base metal, character of drainage water, soil characteristics or other factors?

(*b*) If so, are the results of such investigations available in published reports? What are the references?

(*c*) If the results of your investigations have not been published would it be possible to secure the data for the confidential use of the committee, provided the conditions surrounding the use of the results were made agreeable to you?

4. (*a*) Have you ever given consideration to the establishment of methods for rating the service life of corrugated pipe culverts from the standpoint of durability?

(*b*) If so, have you developed a "rating scale" or other methods for indicating comparative service behavior?

(*c*) Are you willing to make this available for the use of the committee?

5. Do you know of any location in your state (or on your railroad) which would be well suited to a corrugated metal culvert test carried out with the purpose of securing data on the relative behavior of the culvert metals?

6. Does the work as outlined for this committee appeal to you as having possibilities of developing data of real usefulness to the engineering profession?

7. Of what other information not covered by the above questions and which might be helpful to the committee, do you have knowledge?

Forty-two state highway departments and fifty-five of the larger railroad systems have given the sub-committee carefully prepared answers to its questions, and in a number of instances comprehensive laboratory and service data have been submitted. It is evident from this data that the question of comparative values of the different types of base metals is an unsettled one and that many of the largest users would welcome the opportunity to cooperate in further well-directed research work that would assist them in determining the materials best suited for their particular service conditions.

The sub-committee is convinced that the work which it is undertaking to do has far-reaching possibilities and it is moving as rapidly as possible towards some concrete plans for a comprehensive research program that will give reliable information on this important engineering material.

The sub-committee at its March meeting elected H. E. Smith chairman for the coming two years.

Respectfully submitted on behalf of the sub-committee,

J. H. GIBBONEY,
Temporary Chairman.

REPORT OF SECTIONAL COMMITTEE

ON

ZINC COATING OF IRON AND STEEL

The committee held one meeting during the year, in Washington, D. C., March 23, 1928.

Technical Committee I on Hardware and Fastenings.—Owing to the resignation of the first chairman of the technical committee, it has become necessary to reorganize the committee. Its present officers are: A. L. Fox, Chairman; C. L. Pierce, Vice-Chairman; W. F. Markley, Secretary.

The sub-committees have also been reorganized, and definite information is now being sought to enable the sub-committees to formulate specification requirements for the coating on products which fall under their respective scopes.

Technical Committee II on Sheets and Sheet Products, J. T. Hay, chairman, has prepared proposed Specifications for the Zinc Coating on Iron and Steel Sheets. The requirements of these specifications are excerpted from the Standard Specifications for Zinc-Coated (Galvanized) Sheets (Serial Designation: A 93) of the American Society for Testing Materials and include the following sections from those specifications: Sections 1, 4, 5 (*b*), 6, 7, 10, 11, 12, 13 and 14.

The proposed specifications do not include, however, any general reference to the base material.

The proposed specifications, as a whole, were received for publication as tentative as appended hereto.[1] They have been referred to letter ballot of the entire membership of the sectional committee, with the understanding that they would be then transmitted to the sponsor with the request that they be published by that body for one year as tentative. The results of the letter ballot are as follows: Affirmative, 21; negative, 0; not voting, 4. The committee is not yet prepared to recommend these specifications for approval by the American Engineering Standards Committee.

Technical Committee III on Plates, Bars, Structural Shapes and Their Products, V. F. Hammel, chairman, has prepared proposed Tentative Specifications for Zinc (Hot-Galvanized) Coatings on

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[1] See p. 752.—Ed.

Structural Steel Shapes, Plates and Bars and Their Products. These proposed specficiations, with slight changes, were accepted for publication as tentative as appended hereto.[1] They have been referred to letter ballot of the entire membership of the sectional committee, with the understanding that they would be then transmitted to the sponsor with the request that they be published for one year as tentative. The results of the letter ballot are as follows: Affirmative, 21; negative, 0; not voting, 4. The committee is not yet prepared to recommend these specifications for approval by the American Engineering Standards Committee.

Technical Committee IV on Pipes, Conduits and Their Fittings, F. N. Speller, chairman, has submitted Proposed Specifications for Zinc Coatings for Iron or Steel Pipe, for publication as information and for criticism. The proposed specifications are given in the Appendix to this report.

Technical Committee V on Wire and Wire Products, J. C. Johnson, chairman, reports that, while considerable progress has been made by the several sub-committees, the work of none of them has reached a point where the formal publication of specifications for the purpose of information and of criticism seems advisable.

Technical Committee VI on Marine Hardware and Ship Fittings is as yet unorganized, despite considerable correspondence with a view to organizing the committee and having it function.

Technical Committee VII on Methods of Testing, C. D. Hocker, chairman.—The chairman of the technical committee explained at the meeting that his committee is composed practically of one-half of the personnel of the sectional committee and is really a cross-section of all of the technical committees. The personnel of the committee is practically identical with that of Sub-Committee VII on Methods of Testing of Committee A-5 of the American Society for Testing Materials. The committee had had only one request from the members of the other technical committees, namely, for information as to how to provide samples for making tests. The members of the committee were busily engaged in research work, such activity being conducted at the present time as an A.S.T.M. activity.

To this committee has been assigned the duty of correlating and passing on the form and substance of all tentative specifications prepared by the other technical committees.

The officers of the sectional committee have been re-elected for another term of two years.

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[1] See p. 748.—ED.

This report has been submitted to letter ballot vote of the committee, which consists of 48 members; 25 members returned their ballots, of whom 24 have voted affirmatively, none negatively, and 1 has marked his ballot "not voting."

Respectfully submitted on behalf of the committee,

J. A. CAPP,
Chairman.

S. S. TUTHILL,
Secretary

EDITORIAL NOTE

The proposed Specifications for Zinc (Hot-Galvanized) Coatings on Structural Steel Shapes, Plates and Bars and Their Products were accepted for publication as tentative and appear on page 748.

The proposed Specifications for the Zinc Coating on Iron and Steel Sheets were accepted for publication and appear on page 752.

APPENDIX

PROPOSED SPECIFICATIONS
FOR
ZINC COATINGS (GALVANIZING) ON IRON OR STEEL PIPE AND FITTINGS

1. *Scope.*—These specifications cover zinc coatings applied by the hot-dip, electro-deposition, and sherardizing methods to two classes of iron or steel pipe and fittings as follows:

Class I.—Wrought-iron and steel pipe and fittings for conveying air, water or gas and for other purposes where the pipe is ordinarily used without bending.

Class II.—Pipe and fittings for electrical conduit. Only steel pipe is covered under this class.

MATERIAL

2. *Zinc.*—The zinc used for coating by the hot-dip process shall be of any grade of zinc conforming to the requirements of the Standard Specifications for Spelter (Serial Designation: B 6) of the American Society for Testing Materials.[1]

PHYSICAL PROPERTIES AND TESTS

3. (*a*) *Class I.*—Pipe and fittings (standard galvanized pipe and fittings) shall be coated by the hot-dip process both inside and outside.

(*b*) The weight of coating on either the inside or the outside shall not average less than 2 oz. per sq. ft. of coated surface.

(*c*) When specifically called for on the order, pipe of *Class I* shall be subjected to the uniformity of coating test in accordance with Section 5 (*a*).

4. *Class II.*—Pipe and fittings (electrical conduit) may be coated by either the hot-dip, electro-deposition, or sherardizing methods. The test for uniformity of coating shall be made in accordance with Section 5.

5. (*a*) *Uniformity of Coating Test.*—Hot-dip galvanized pipe of Class II shall stand four dips under the Preece Test as described in the appendix to the Standard Methods of Determining Weight of Coating on Zinc-Coated Articles (Serial Designation: A 90) of the American Society for Testing Materials[2] without failure on either the outside or inside surface. Before testing, all paint, enamel or other substances on the surface shall be completely removed by the use of chloroform or, where necessary, by a suitable solvent. If other coatings approved by the Underwriters' Laboratories, Inc., are applied to the inside surface the Preece test shall not apply to the interior of the pipe.

(*b*) Electroplated and sherardized pipe and fittings shall be tested for uniformity of coating by the Preece Test as described in the Standard Methods A 90[2] and shall stand two dips without failure after removing all paint and enamel. This test shall only be required on the outside surface of the pipe.

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[1] 1927 Book of A.S.T.M. Standards, Part I, p. 524.

[2] *Ibid.*, p. 343.

6. *Bend Test.*—Pipe of *Class II* shall stand being bent 90 deg. around a mandrel the radius of which is 7 times the nominal diameter of the pipe without causing the coating to crack or flake. The bend tests shall be made at room temperature.

NOTE.—The uniformity of coating test is intended only to detect the thinner points in coatings of the *same* type, and is not to be construed as differentiating between different types of coatings.

7. *Test Specimens.*—Test specimens shall consist of sections cut from a coated pipe.

8. *Number of Tests.*—One of each of the tests specified in Sections 5 and 6 may be made on a length of pipe in each lot of 500 lengths or fraction thereof of each size.

9. *Retests.*—If the results of either of the tests of any lot do not conform to the requirements of these specifications, retests of two additional pipes shall be made, each of which shall conform to the requirements specified.

FINISH

10. The zinc coating on pipe and fittings shall be free from injurious defects such as uncoated spots, excessive roughness and lumps. The finish of Class II pipe and fittings shall also conform to the requirements for rigid electrical conduit of the Underwriters' Laboratories, Inc.

INSPECTION AND REJECTION

11. *Inspection.*—The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the coating of the pipe ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the pipe is being coated in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

12. *Rejection.*—Pipe represented by test specimens which fail to conform to the requirements of these specifications will be rejected and the manufacturer shall be notified.

REPORT OF COMMITTEE A-6

ON

MAGNETIC PROPERTIES

The work of Committee A-6 has been confined chiefly to the activities of its sub-committees. Only one meeting of the main committee was held during the year.

Sub-Committee I on Definitions and Nomenclature, W. J. Shackelton, chairman, is submitting for publication as information a revised and enlarged set of magnetic terms and definitions appearing in the Appendix to this report. The symbols are in complete accordance with those adopted by the American Institute of Electrical Engineers. Suggestions and criticisms are particularly invited.

Sub-Committee II on Tests at Low Inductions and High Frequencies, R. L. Sanford, chairman, has had the test at 1000 cycles appearing in the Tentative Method of Test for Magnetic Properties of Iron and Steel at Low Inductions for Audio and Power Frequencies (A 34 – 27 T)[1] under consideration and recommends a number of revisions. The revisions, although minor, are rather extensive and the methods are accordingly appended hereto[2] in their proposed revised form. The sub-committee recommends that the method, as revised, be advanced to standard to be added to the present Standard Methods of Magnetic Properties of Iron and Steel (A 34 – 27).[3]

Sub-Committee III on Methods of Test at High Magnetizing Forces has been reorganized under the leadership of Mr. L. E. Howard. The sub-committee, as now made up, consists of the following: Thomas Spooner, *ex-officio*, J. A. Capp, F. P. Fahy, J. A. Matthews, B. G. Babbitt, A. P. Spooner, R. L. Sanford and L. A. Howard, chairman. A preliminary survey has been made to ascertain what experimental facilities are available and to determine the proper scope of the sub-committee's investigations. Active work is now under way on the problem.

By letter ballot, this committee has re-elected the present officers to serve for the ensuing two years.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 698 (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 765.

[2] See 1928 Supplement to Book of A.S.T.M. Standards, p. 29.—Ed.

[3] 1927 Book of A.S.T.M. Standards, Part I, p. 354.

This report has been submitted to letter ballot of the committee, which consists of 13 members; 11 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee.

THOMAS SPOONER,
Chairman.

R. L. SANFORD,
Secretary.

EDITORIAL NOTE

The Tentative Method of Test for Magnetic Properties of Iron and Steel at Low Inductions for Audio and Power Frequencies were approved at the annual meeting as revised by the committee and were subsequently adopted as standard by letter ballot of the Society on September 1, 1928, to be added to the present Standard Methods of Test for Magnetic Properties of Iron and Steel. The complete standard methods in their latest revised form appear in the 1928 Supplement to Book of A.S.T.M. Standards.

APPENDIX

PROPOSED STANDARDIZATION OF MAGNETIC TERMS, UNITS, AND SYMBOLS

In the following list of definitions the term defined is given first followed in parenthesis by any optional alternative terms which may be used when the context clearly indicates the intended conception. The symbol for the quantity is then given wherever such symbol is in use, followed by the definition of the standard term.

The name of the unit employed is included, together with the definition of the unit.

BASIC CONCEPTIONS

Magnetic Field (Field).—A portion of space in which a magnetic state exists.

Unit: Not required.

Magnetic Flux (Flux), Φ.—The magnetic quantity which by its variation is capable of producing in an associated electric circuit an electromotive force proportional to its time rate of variation.

Unit: Maxwell.—The maximum value of the magnetic flux, the uniform variation of which between zero and its full value in one second induces one c.g.s. unit of electromotive force in a single turn electric circuit enclosing the flux.

Magnetomotive Force, $\mathcal{F}$.—The total magnetizingi nfluence acting on any part of a magnetic circuit.

Unit: Gilbert.—The magnetomotive force resulting from a current in an electric circuit of any number of turns linked with the magnetic circuit when the product of the current in amperes by the number of turns is $\frac{1}{0.4\pi}$

NOTE.—When a current of I amperes is flowing in a circuit of N turns, $\mathcal{F} = 0.4\,\pi\,N\,I$.

Magnetic Force (Magnetizing Force, Field Intensity), H.—The space rate of variation of magnetomotive force at any point in the magnetic circuit.

Unit: Gilbert per centimeter.—The magnetic force when the magnetomotive force varies at the rate of one gilbert per centimeter.

NOTE.—At the center of an infinitely long solenoid having n turns per centimeter in which a current of I amperes is flowing, $H = 0.4\,\pi\,n\,I$.

DERIVED CONCEPTIONS

Induction (Flux Density), B.—The flux per square centimeter of any area normal to the direction of the induction.

Unit: Gauss.—An induction of one Maxwell per square centimeter.

Normal Induction, B.—The induction in a magnetic material corresponding to a given magnetic force when the material is in a symmetrically cyclic magnetic condition with respect to the given magnetic force.

Unit: Same as for *Induction*.

Intrinsic Induction (Ferric Induction), B_i.— The excess of the normal induction over that corresponding to the same magnetic force in empty space.

Unit: Same as for *Induction.*

Saturation Induction, B_s.—The maximum intrinsic induction possible in a material.

Unit: Same as for *Induction.*

Permeability, μ.—When used without a qualifying adjective, understood to be the normal permeability as defined below.

Unit: Not required.

Normal Permeability, μ.—The ratio of the normal induction to the corresponding magnetic force.

Unit: Not required.

Initial Permeability, μ_0.—The normal permeability when both the magnetic force and the induction are vanishingly small.

Unit: Not required.

Differential Permeability, μ_d.—The ratio of the positive increase of normal induction to the positive increase of magnetic force when these increases are vanishingly small.

Unit: Not required.

Incremental Permeability, $\mu_\triangle$.—The ratio of the cyclic change in induction to the corresponding cyclic change in magnetic force when the mean induction differs from zero.

Unit: Not required.

Reversible Permeability, μ_r.—The incremental permeability when the change in induction is vanishingly small.

Unit: Not required.

Intrinsic Permeability, μ_i.—The ratio of the intrinsic induction to the corresponding magnetic force.

Unit: Not required.

Permanence, $\mathscr{P}$.—The property of any part of a magnetic circuit which determines the flux corresponding to a given magnetomotive force.

NOTE.—Permeance $= \frac{\Phi}{\mathscr{F}}$ equivalent to $\frac{\mu A}{l}$ for uniform μ.

where μ = permeability;
A = area in square centimeters; and
l = length in centimeters.

Unit: Not required.

Reluctivity, ν.—The reciprocal of permeability.

Unit: Not required.

Reluctance, $\mathscr{R}$.—The reciprocal of permeance.

NOTE.—Reluctance $= \frac{\mathscr{F}}{\Phi} = \frac{l}{\mu A}$ for uniform μ.

Unit: Not required.

Remanence.—The magnetic induction which remains in a magnetic circuit after the removal of an applied magnetic force.

Unit: Same as for *Induction.*

Residual Induction, B_r.—The magnetic induction which remains in a magnetic material when the effective magnetic force has been reduced to zero.

NOTE.—When the material is in a symmetrically cyclic magnetic condition, the residual induction is called the *normal* residual induction.

Unit: Same as for *Induction.*

Retentivity.—The property of a material measured by the normal residual induction remaining after the removal of an applied magnetic force corresponding to the saturation induction for the material.

Unit: Same as for *Induction.*

Coercive Force, H_c.—The reversed magnetic force that is just sufficient to reduce the residual induction in a material to zero.

NOTE.—When the residual induction is the *normal* residual induction, the coercive force required is called the *normal* coercive force.

Unit: Same as for *Magnetic Force.*

Coercivity.—The property of a material measured by the coercive force required to reduce to zero the induction remaining after the removal of an applied magnetic force corresponding to the saturation induction for the material.

Unit: Same as for *Magnetic Force.*

Core Loss (Iron Loss), *W.*—The power expended in a magnetic material subjected to a varying induction.

Eddy Current Loss, W_e.—The part of the core loss due to currents circulating in the magnetic material as a result of electromotive forces induced by the varying induction.

Hysteresis Loss, W_h.—The part of the core loss due to so-called hysteresis effects.

Standard Core Loss, $W_{B/f}$.—The total power in watts per kilogram expended in the magnetic material which is subjected to a harmonically varying induction of a specified maximum value B and of a specified frequency f.

Aging (of magnetic materials).—The normal or accelerated change in magnetic properties of a magnetic material under continued normal or specified artificial aging conditions. When used in reference to core loss this term, unless otherwise modified, implies an increase in loss. When used in reference to permeability or remanence the term, in a positive sense, indicates a decrease in these quantities.

REPORT OF COMMITTEE A-8
ON
MAGNETIC ANALYSIS

The committee has held, during the year, two well attended meetings, one at French Lick, Ind., June 22, 1927, and one at Washington, D. C., on March 21, 1928. At the latter meeting it was decided that in view of the apparent confusion in the minds of many with regard to the subject, it would be desirable to give a brief statement concerning the nature of magnetic analysis, its present status, and the relation of Committee A-8 to its development.

There is probably at the present time no subject of more lively interest in the field of the testing of materials than that of non-destructive testing. A satisfactory non-destructive testing method must be based upon the measurement of some physical property which can be determined without injury to the material tested and which bears a definite and determinable relation to the desired mechanical characteristics. Magnetic tests can be made without injury to the material and, moreover, there is abundant experimental evidence of a very definite and close connection between the magnetic properties of ferro-magnetic materials and their mechanical properties. In view of this fact, a considerable amount of effort has been devoted in recent years to the study of this relationship with the object in view of developing practical non-destructive methods of test, applicable on a commercial scale. In order to distinguish between magnetic testing in general and magnetic testing carried out for the purpose of indicating mechanical quality or soundness, the term "magnetic analysis" has been adopted to designate the latter. Obviously, the term covers not only the process of testing itself but also the interpretation of the results in terms of the desired mechanical characteristics.

As to the present status of magnetic analysis, it is only fair to admit that it is still in the experimental stage. A number of practical applications having definite commercial value have been made, and serve to demonstrate beyond a doubt that magnetic methods can be successfully applied. On the other hand, due to the lack of knowledge of the fundamental relationships involved, it is generally not possible to extend the methods to other applications without first carrying out investigations on the individual problems. It is necessary, therefore, in order to promote the practical development of magnetic analysis, to extend our knowledge of the fundamental relationships, which are not simple, to develop new and superior methods of test and to continue the study of the application of magnetic methods to the solution of specific commercial problems.

The American Society for Testing Materials seeks to promote the development of magnetic analysis along the lines suggested above through the activities of Committee A-8, which was organized in 1918 for that purpose. The committee functions in two ways: first, as a clearing house for the interchange of ideas and data among its own members and for the dissemination of information through the medium of reports and technical papers, and, second, by carrying out cooperative investigations in which the various points of view and methods represented among its membership can be brought to bear on a single problem. The degree to which the committee has contributed to the advancement of magnetic analysis is indicated to some extent by the score or more of reports and technical papers published in the *Proceedings* of the Society and elsewhere.

Three investigations have been undertaken by the committee, the technical details of which it is not necessary to discuss here. The first work was on twist drills of high-speed steel. A comprehensive report of this investigation was given in a paper by Kouwenhoven at the annual meeting in 1924.[1] A second investigation on high-speed steel drills with welded shanks was undertaken and a considerable amount of work done. Completion of this work was deferred, however, until after the results of an investigation of a more fundamental nature on specially prepared specimens of high-speed steel were in hand. The investigation on high-speed steel has yielded a large amount of data and various phases have been reported from time to time, the most complete report having been given by Spooner in a paper presented at the annual meeting in 1926.[2] The specimens prepared for this investigation are, for the most part, intact and provide excellent material for trying out new methods from time to time. In addition to the magnetic tests, X-ray examination was made on a number of the samples. The results given by St. John in an appendix to the committee's report in 1927[3] confirmed in general the conclusions arrived at from a consideration of the magnetic data. It is now proposed to take up again the investigation of the second series of drills and to undertake a new investigation of a fundamental nature on a commercially important type of steel having a more simple composition and structure.

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[1] W. B. Kouwenhoven, "Magnetic Tests of A.S.T.M. Drills," *Proceedings*, Am. Soc. Testing Mats., Vol. 24, Part II, p. 635 (1924).

[2] Thomas Spooner, "The Magnetic Analysis of High-Speed Steel," *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part II, p. 116 (1926).

[3] Ancel St. John, "X-ray Studies of High-Speed Steel," Report of Committee A-8 on Magnetic Analysis, Appendix III, *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 247 (1927).

In conclusion, it may be well to point out some of the things that are needed to promote the more rapid development of magnetic analysis to the point where it can take its proper place as a practical method of great value for routine inspection and for research on the properties of ferro-magnetic materials. These needs include more workers, less secrecy and a greater degree of cooperation. It should be needless to point out that the present great usefulness of the metallurgical microscope was brought about by the efforts of a much larger number of investigators than have ever been engaged on the problems of magnetic analysis. It is not altogether unreasonable to expect that the rate of progress bears a rather definite relation to the number of investigators engaged in the field. There seems to be a tendency on the part of industry in general, which, it is to be hoped, is more apparent than real, to let the burden of development rest on a very small number. It is doubtful if there will be a corresponding reluctance in taking advantage of the benefits when final successful development has been achieved.

In this day and age, the element of secrecy in scientific development should require no more than passing mention. It would probably be astonishing, however, if it could be known how many, after hearing of the possibilities of magnetic analysis for the first time, have retired to their laboratories to work in secret, and, after discovering independently many of the pitfalls into which an experimenter may fall when entering a new and unfamiliar field, have come to the conclusion that most of the claims made for magnetic analysis are not warranted.

The field of magnetic analysis is a wide one, including the realms of magnetism, physical metallurgy and mechanics. No one familiar with only one field can logically hope to solve the problem alone. It is only by close and sympathetic cooperation that the greatest good for the greatest number can be accomplished. It is with this thought in mind that the membership of Committee A-8 has been made up, for it includes workers in all of these fields. Moreover, the committee offers its cooperation and seeks that of all who desire to contribute to the general advance of magnetic analysis either from the point of view of theoretical development or from that of practical application.

By letter ballot, the committee has re-elected the present officers to serve for the ensuing two years.

This report has been submitted to letter ballot of the committee, which consists of 13 members, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

R. L. SANFORD,
Chairman.

A. V. DE FOREST,
Secretary.

REPORT OF COMMITTEE B-1

ON

COPPER WIRE

In the report for 1927 it was stated that the personnel of Committee B-1 was identical with that of the Sectional Committee on Copper Wire organized under the sponsorship of the Society in accordance with the procedure of the American Engineering Standards Committee. This report of Committee B-1 may, therefore, be considered equally as the report of the Sectional Committee where it covers matters within the purview of the Sectional Committee.

There have been no developments during the year in the matter of the Tentative Specifications for Bronze Trolley Wire (B 9 - 26 T) and the specifications should, therefore, be continued as tentative until full and final agreement is reached with the American Electric Railway Association in cooperation with which the specifications were developed.

There are no revisions to be offered at this time in any other of the specifications within the charge of Committee B-1.

In its capacity as the Sectional Committee, consideration has been given the Standard Specifications for Hard-Drawn Copper Wire (B 1 - 27) and for Medium-Hard-Drawn Copper Wire (B 2 - 27). These specifications had been questioned by the representatives of the National Electric Light Association on the basis of their adaptability for transmitting electrical power. At a meeting held in March, 1928, the committee voted to recommend that the Standard Specifications for Hard-Drawn Copper Wire (B 1 - 27)[1] be offered for approval by the American Engineering Standards Committee as American Standard. This action has subsequently been confirmed by letter ballot, the results of which are given at the end of the report.

At the same meeting the committee voted to submit to a formally constituted sub-committee the study of the question of proper specifications for wire and cable for the construction of electric power lines. This sub-committee is now being organized.

The letter ballot of the Sectional Committee, which consists of 21 members, on the submission of Specifications B 1 - 27 for approval as American Standard resulted as follows: Affirmative, 19; negative, 1; members registering "not voting," 1; unreturned ballots, 0.

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[1] 1927 Book of A.S.T.M. Standards, Part I, p. 547.

The present officers of the committee have been re-elected for the ensuing two years.

This report has been submitted to letter ballot of the committee, which consists of 21 members, all of whom have voted affirmatively.

Respectfully submitted on behalf of Committee B-1 (also Sectional Committee on Copper Wire),

J. A. CAPP,
Chairman.

REPORT OF COMMITTEE B-2
ON
NON-FERROUS METALS AND ALLOYS

During the past year, Committee B-2 has held one meeting in New York on March 21. Its sub-committees have again been very active and in consequence of their work the committee is making the following recommendations:

I. Four new tentative standards are being submitted;

II. Five revisions of present standards are being proposed, the revisions of three standards proposed last year being continued as tentative;

III. Eight tentative standards are being recommended for advancement to standard;

IV. The revision of one tentative standard is recommended;

V. Six tentative standards are being continued as tentative without revision.

Recommendations Affecting Standards and Tentative Standards

The recommendations affecting standards and tentative standards are presented first in summarized form together with an analysis of the letter ballot on each item. They are then referred to where necessary, in greater detail, being grouped for convenience in the order of the sub-committees directly responsible for them.

I. New Tentative Standards.—The committee submits for publication as tentative the following four new specifications as appended hereto:[1]

Proposed Tentative Specifications for Fire-Refined Copper Other than Lake;
Proposed Tentative Specifications for Seamless Copper Tubes;
Proposed Tentative Specifications for Sand Castings of the Alloy: Copper 80 per cent; Tin 10 per cent; Lead 10 per cent;
Proposed Tentative Specifications for Silver Solders.

II. Tentative Revisions of Standards.—The committee recommends that the revisions of the following standards be accepted for publication as tentative as given in detail in the recommendations of the sub-committees:

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[1] See pp. 763, 778, 766, and 774, respectively.—Ed.

Standard Specifications for Free-Cutting Brass Rod for Use in Screw Machines (B 16 - 18);[1]
Standard Specifications for Naval Brass Rods for Structural Purposes (B 21 - 27);[1]
Standard Specifications for Brass Ingot Metal, Graded and Ungraded, for Sand Castings (B 30 - 22);[1]
Standard Specifications for Bronze Bearing Metal in Ingot Form (B 31 - 21);[1]
Standard Methods of Chemical Analysis of Manganese Bronze (B 27 - 19).[1]

III. Tentative Standards Advanced to Standard.—The committee recommends that the following eight tentative standards be advanced to standard:

Tentative Specifications for Brazing Solder (B 64 - 27 T);[2]
Tentative Specifications for Aluminum Bronze Castings (B 59 - 26 T);[3]
Tentative Specifications for Sand Castings of the Alloy: Copper 88 per cent; Tin 8 per cent; Zinc 4 per cent (B 60 - 26 T)[3] as revised;
Tentative Specifications for Steam or Valve Bronze Sand Castings (B 61 - 26 T)[3] as revised;
Tentative Specifications for Composition Brass or Ounce Metal Sand Castings (B 62 - 26 T);[3]
Tentative Specifications for Yellow Brass Sand Castings for General Purposes (B 65 - 27 T);[4]
Tentative Specifications for Bronze Castings in the Rough for Locomotive Wearing Parts (B 66 - 27 T);[4]
Tentative Specifications for Car and Tender Journal Bearings, Lined (B 67 - 27 T).[4]

IV. Proposed Revisions of Tentative Standards.—The committee recommends that the proposed revisions of the Tentative Methods of Chemical Analysis of Aluminum and Light Aluminum Alloys (B 40 - 27 T)[5] as given in detail in the recommendations of Sub-Committee VII be approved and that the methods as revised be continued as tentative.

The committee also recommends that the tentative revisions of the following standards as proposed in 1927 be continued as tentative:

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[1] 1927 Book of A.S.T.M. Standards, Part I, pp. 646, 655, 582, 586, 700.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 706 (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 91.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, pp. 697–712 (1926); also 1927 Book of A.S.T.M. Tentative Standards, pp. 105–120.

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, pp. 714–724 (1927); also 1927 Book of A.S.T.M. Tentative Standards, pp. 121–131.

[5] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 740 (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 152.

Standard Specifications for Cartridge Brass (B 19 – 19);[1]
Standard Specifications for Cartridge Brass Disks (B 20 – 19);[1]
Standard Specifications for Seamless Admiralty Condenser Tubes and Ferrule Stock (B 44 – 24).[1]

V. Tentative Specifications Continued as Tentative.—The following specifications are recommended for continuation as tentative without revision:

Tentative Specifications for Copper Tubing for Refrigerators (B 68 – 27 T);[2]
Tentative Specifications for Rolled Zinc (B 69 – 27 T);[2]
Tentative Specifications for Aluminum Ingots for Remelting (B 24 – 26 T);[3]
Tentative Specifications for Aluminum Sheet (B 25 – 26 T);[3]
Tentative Specifications for Aluminum-Base Sand-Casting Alloys in Ingot Form (B 58 – 26 T);[3]
Tentative Specifications for Aluminum-Base Alloy Sand Castings (B 26 – 26 T).[3]

The above recommendations have been submitted to letter ballot of the committee, which consists of 115 members; 54 members returned their ballots. The analysis of the vote of the committee is given in the following table:

Items	Affirmative	Negative	Not Voting
I. New Tentative Standards			
Proposed Specifications for Fire-Refined Copper Other than Lake	32	0	17
Proposed Specifications for Seamless Copper Tubes	27	0	22
Proposed Specifications for Sand Castings of the Alloy: Copper 80 per cent; Tin 10 per cent; Lead 10 per cent	34	0	15
Proposed Specifications for Silver Solders	30	0	19
II. Tentative Revisions of Standards			
B 16 – 18. Specifications for Free-Cutting Brass Rod for Use in Screw Machines	28	0	21
B 21 – 27. Specifications for Naval Brass Rods for Structural Purposes	26	0	23
B 30 – 22. Specifications for Brass Ingot Metal, Graded and Ungraded, for Sand Castings	30	0	19
B 31 – 21. Specifications for Bronze Bearing Metal in Ingot Form	32	0	17
B 27 – 19. Methods of Chemical Analysis of Manganese Bronze	35	0	14
III. Advancement of Tentative Standards to Standard			
B 64 – 27 T. Specifications for Brazing Solder	37	0	12
B 59 – 26 T. Specifications for Aluminum Bronze Castings	39	0	10
B 60 – 26 T. Specifications for Sand Castings of the Alloy: Copper 88 per cent; Tin 8 per cent; Zinc 4 per cent	34	1	14
B 61 – 26 T. Specifications for Steam or Valve Bronze Sand Castings	34	0	15
B 62 – 26 T. Specifications for Composition Brass or Ounce Metal Sand Castings	35	0	14
B 65 – 27 T. Specifications for Yellow Brass Sand Castings for General Purposes	34	0	15
B 66 – 27 T. Specifications for Bronze Castings in the Rough for Locomotive Wearing Parts	31	0	18
B 67 – 27 T. Specifications for Car and Tender Journal Bearings, Lined	31	0	18
IV. Proposed Revisions of Tentative Standards			
B 40 – 27 T. Chemical Analysis of Aluminum and Light Aluminum Alloys	35	0	14

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, pp. 1092–1093 (1927); also 1927 Book of A.S.T.M. Tentative Standards, pp. 766–767.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, pp. 725–736 (1927); also 1927 Book of A.S.T.M. Tentative Standards, pp. 137–148.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, pp. 713–717, 691–696 (1926); also 1927 Book of A.S.T.M. Tentative Standards, pp. 132–136, 94–99.

ACTIVITIES OF SUB-COMMITTEES

Sub-Committee I on Pure Metals in Ingot Form (W. H. Bassett, chairman).—This sub-committee is submitting new specifications for fire-refined copper other than lake, in order to make the specifications for copper complete. The history of these new specifications dates back to the time just after the writing of the specifications for lake copper and electrolytic copper, when an attempt was made to formulate a specification for casting copper. This material was found to be so miscellaneous, being produced by fire-refining processes from ores in some cases and from secondary sources in others, that it appeared to be impossible to bring about a satisfactory specification and the matter was given up with the publication of "The Classification of American Copper"[1] in the report of Committee B-2 for 1913. In 1926 it was found that a brand of casting copper was in use by a number of manufacturers in the making of alloys, and also that it was being rolled into sheets and rods. It was also found that several of the other copper refiners were producing copper by fire-refining methods from ores which did not contain sufficient precious metals to make electrolytic refining pay. These brands which did not contain sufficient impurities to destroy their usefulness for the making of certain alloys or for the manufacture of sheets or rods for other than electrical purposes, were sufficiently well established in the market to make specifications appear advisable and the result was the Proposed Specifications for Fire-Refined Copper Other than Lake which are recommended for publication as tentative as appended to this report.[2]

Sub-Committee II on Wrought-Metals and Alloys (W. Reuben Webster, chairman).—This sub-committee is recommending for publication as tentative new Specifications for Seamless Copper Tubes as appended hereto.[3]

No criticisms of the Tentative Specifications for Brazing Solder (B 64 – 27 T)[4] having been received, it is recommended that these specifications be advanced to standard.

It is further recommended that the following revisions of the Standard Specifications for Free-Cutting Brass Rod for Use in Screw Machines (B 16 – 18) and the Standard Specifications for Naval Brass Rods for Structural Purposes (B 21 – 27) be accepted for publication as tentative revisions:

Standard Specifications for Free-Cutting Brass Rod for Use in Screw Machines (B 16 – 18).[5]

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[1] Report of Committee B-2 on Non-Ferrous Metals and Alloys, *Proceedings*, Am. Soc. Testing Mats., Vol. XIII, p. 206 (1913).

[2] See p. 763.—ED.

[3] See p. 778.—ED.

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 706 (1927); also 1927 Book of A.S.T.M Tentative Standards, p. 91.

[5] 1927 Book of A.S.T.M. Standards, Part I, p. 646.

Section 3.—Change the requirement for lead content from "2.25–3.25 per cent" to "2.50 – 3.75 per cent," and change the requirement for materials other than copper, lead and zinc from "not over 0.25 per cent" to "not over 0.50 per cent."

Section 5.—Omit Paragraph (*a*) reading as follows, re-numbering Paragraph (*b*), calling it Section 5:

> 5. (*a*) Analyses of separate rods may be made by the purchaser. The copper and lead contents thus determined shall lie within the following limits:
>
> | | |
> |---|---|
> | Copper................................ | 59.4 – 63.6 per cent |
> | Lead................................ | 1.8 – 3.9 " |

Section 6.—Change from its present form: namely,

> Rods or bars shall bend cold through an angle of 120 deg. around a pin the diameter of which is equal to twice the diameter or thickness of the rod or bar, without fracture (Note 3).

to read as follows:

> Rods or bars shall stand being bent cold through an angle of 120 deg. around a pin, the diameter of which is equal to twice the diameter of the round rods or four times the thickness of other shapes, without fracturing (Note 3).

Section 8.—Replace the present table of permissible variations by the following:

DIAMETER, OR DISTANCE BETWEEN PARALLEL FACES	PERMISSIBLE VARIATION ROUNDS	 OTHER SHAPES
Up to ½ in., inclusive.........	± 0.0015 in.	± 0.003 in.
Over ½ to 1 in., inclusive......	± 0.002 in.	± 0.004 in.
Over 1 to 2½ in., inclusive.....	± 0.0025 in.	± 0.005 in.
Over 2½ in..................	± 0.15 per cent	± 0.30 per cent

Standard Specifications for Naval Brass Rods for Structural Purposes (B 21 – 27).[1]

Section 10.—Revise the table of permissible variations to agree with the table of permissible variations recommended for Specifications B 16 – 18 above.

It is also recommended that the tentative revisions recommended in 1927 in the following standard specifications be continued as tentative:

Standard Specifications for Cartridge Brass (B 19 – 19);[2]
Standard Specifications for Cartridge Brass Disks (B 20 – 19);[2]
Standard Specifications for Seamless Admiralty Condenser Tubes and Ferrule Stock (B 44 – 24).[2]

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[1] 1927 Book of A.S.T.M. Standards, Part I, p. 655.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 27 Part I, pp. 1092–1093 (1927); also 1927 Book of A.S.T.M. Tentative Standards, pp. 766–767.

The sub-committee also recommends that the Tentative Specifications for Copper Tubing for Refrigerators (B 68 – 27 T)[1] be continued as tentative for another year without revision.

Sub-Committee III on Sand-Cast Metals and Alloys (N. K. B. Patch, chairman).—This sub-committee is recommending for publication as tentative, new Specifications for Sand Castings of the Alloy: Copper 80 per cent; Tin 10 per cent; Lead 10 per cent, as appended hereto.[2] These specifications have originated entirely within the sub-committee. As a result of consideration given by the members to the types of alloys currently produced it was decided that this particular one was a very commonly used alloy and should be standardized by the Society.

No criticisms having been received during the year it is recommended that the following three tentative specifications be advanced to standard without revision:

Tentative Specifications for Aluminum Bronze Castings (B 59 – 26 T);[3]
Tentative Specifications for Composition Brass or Ounce Metal Sand Castings (B 62 – 26 T);[3]
Tentative Specifications for Yellow Brass Sand Castings for General Purposes (B 65 – 27 T).[4]

It is further recommended that the following tentative specifications be advanced to standard revised as indicated:

Tentative Specifications for Sand Castings of the Alloy: Copper 88 per cent; Tin 8 per cent; Zinc 4 per cent (B 60 – 26 T).[5]

Section 5 (*a*).—Change from its present form: namely,

5. (*a*) The alloy shall conform to the following requirements as to tensile properties:

Tensile Strength, min., lb. per sq. in.	40 000
Yield Point, min., lb. per sq. in.	15 000
Elongation in 2 in., min., per cent	20

to read as follows:

5. (*a*) The alloy shall conform to the following minimum requirements as to tensile properties:

Tensile Strength, lb. per sq. in.	35 000
Yield Point, lb. per sq. in.	15 000
Elongation in 2 in., per cent	15

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[1] *Proceedings*, Am. Soc. Testing Mat., Vol. 27, Part I, p. 725 (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 137.

[2] See p. 766.—ED.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, pp. 697 and 709 (1926); also 1927 Book of A.S.T.M. Tentative Standards, pp. 105 and 117.

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 714 (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 121.

[5] *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, p. 701 (1926); also 1927 Book of A.S.T.M. Tentative Standards, p. 109.

Tentative Specifications for Steam or Valve Bronze Sand Castings (B 61 - 26 T).

Section 3 (*a*).—Change the phrase at the end of the table of chemical requirements from "Total other impurities, per cent" to read "Total other impurities in addition to those specified above, per cent."

It is recommended that the revision of the Standard Specifications for Brass Ingot Metal, Graded and Ungraded, for Sand Castings (B 30 - 22),[1] as appended hereto[2] in the form of separate tentative specifications, be accepted for publication as tentative and that the Standard Specifications be withdrawn. This revision involves a change in the requirements for chemical composition of the seven grades of alloys and the addition of another grade. Grade No. 1 has been revised to conform to the requirements for chemical composition of the Tentative Specifications for Steam or Valve Bronze Sand Castings (B 61 - 26 T) and Grade No. 2 to the requirements of the Tentative Specifications for Composition Brass or Ounce Metal Sand Castings (B 62 - 26 T). In Grades Nos. 3, 4 and 5, a requirement for nickel has been added and a change made in the permissible iron content. The compositions of Grades 6 and 7 have been entirely revised and a new composition added, Grade 8, conforming to the requirements of the proposed Standard Specifications for Yellow Brass Sand Castings for General Purposes (B 65).

The sub-committee further recommends that the following be published for one year as a tentative revision of the Standard Specifications for Bronze Bearing Metal in Ingot Form (B 31 - 21)[3] before referring it to letter ballot of the Society for adoption as standard:

Section 3.—Replace the present table of requirements for chemical composition with the following:

Alloy, Grade No.	Copper, per cent	Tin, per cent	Lead, per cent	Phosphorus, per cent	Impurities, maximum, per cent						Constituents Other than Copper, Tin, Lead and Phosphorus, per cent
					Zinc	Iron	Nickel	Antimony	Aluminum	Sulfur	
1........	85	10	5	0.70[a]	0.25	0.25	0.25	0.75	none	0.05	0.50 - 1.00
2........	80	10	10	0.70[a]	0.50	0.25	0.25	0.75	none	0.05	0.75 - 1.25
3........	80	10	10	0.05[b]	2.00	0.25	0.25	0.75	none	0.05	2.50 - 3.00
4........	77	8	15	0.25[b]	0.50	0.25	0.25	0.75	none	0.05	0.75 - 1.25
5........	73	7	20	0.05[b]	0.50	0.25	0.25	0.75	none	0.05	1.00 - 1.25
6........	70	5	25	none	0.50	0.25	0.25	0.75	none	0.05	1.00 - 1.25

[a] Minimum. [b] Maximum.

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[1] 1927 Book of A.S.T.M. Standards, Part I, p. 582.

[2] See p. 770.—ED.

[3] 1927 Book of A.S.T.M. Standards, Part I, p. 586.

Section 4.—In the table of permissible variations for the percentage of elements specified over 10 per cent, change the permissible variations over and under the specified value from "1.50 per cent" to "2.00 per cent."

Sub-Committee VI on Non-Ferrous Alloys for Railroad Equipment (G. H. Clamer, chairman).—This sub-committee recommends that the Tentative Specifications for Bronze Castings in the Rough for Locomotive Wearing Parts (B 66 - 27 T)[1] and the Tentative Specifications for Car and Tender Journal Bearings, Lined (B 67 - 27 T)[1] be advanced to standard since no criticisms have been received during the past year.

Sub-Committee VII on Methods of Chemical Analysis (W. A. Cowan, chairman).—This sub-committee recommends that the following revisions be published as a tentative revision of the Standard Methods of Chemical Analysis of Manganese Bronze (B 27 - 19):[2]

Under the Determination of Manganese by the Persulfate Method, change the description under Method from its present form; namely,

> In a 250-cc. Erlenmeyer flask dissolve 1 g. of bronze in 24 cc. of the "solution for dissolving." Allow to stand on a steam bath or hot plate until entirely dissolved, and until the oxides of nitrogen are expelled. Add 15 cc. of $AgNO_3$ solution and 20 cc. of ammonium persulfate and leave on the steam bath until the solution has developed a full permanganate color and no bubbles can be seen to come off when the flask is given a whirling motion. Cool to below 25° C. in running water, and add 50 cc. of cold water. Titrate with standard sodium-arsenite solution to the disappearance of the pink color.

to read as follows:

> Adjust the size of sample to the expected percentage so that the portion taken does not contain more than 0.002 g. manganese. Place it in a 250-cc. Erlenmeyer flask with 24 cc. of the "solution for dissolving" and heat until solution is complete. Boil until oxides of nitrogen are expelled. Dilute to 100 cc. with boiling-hot water, add 20 cc. of $AgNO_3$ solution and 30 cc. of the persulfate solution, then remove to a moderately warm place to stand for a few minutes for complete development of the permanganic acid. Cool to below 25° C., and titrate with the standard arsenite solution to the disappearance of the pink color.

The sub-committee further recommends that the following revisions be made in the Tentative Methods of Chemical Analysis of Aluminum and Light Aluminum Alloys (B 40 - 27 T):[3]

Under (*a*) *Persulfate Method* for the Determination of Manganese under the Analysis of Aluminum, change the description of the Standard Sodium Arsenite Solution from its present form: namely,

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, pp. 718–724 (1927); also 1927 Book of A.S.T.M. Tentative Standards, pp. 125–131.

[2] 1927 Book of A.S.T.M. Standards, Part I, p. 700.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 740 (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 152.

Mix 200 cc. of the stock sodium arsenite solution with 2500 cc. of distilled water, and standardize by the method described below against a steel or iron of known manganese content. One cubic centimeter of this solution should be equivalent to approximately 0.00050 g. of manganese.

to read as follows:

Mix 200 cc. of the stock sodium arsenite solution with 2500 cc. of distilled water, and standardize against a measured volume of a standard $KMnO_4$ solution that has been reduced and treated as in the method, or against a suitable standard metal or alloy of the U. S. Bureau of Standards. One cubic centimeter of this solution should be equivalent to approximately 0.00035 g. of manganese.

Change the description of the Method from its present form: namely,

In a 250-cc. Erlenmeyer flask, dissolve 1 g. of the sample in 30 cc. of acid mixture by warming on a water bath until solution is complete. Boil until oxides of nitrogen are expelled. Dilute to 100 cc. with boiling-hot water, remove the flask from the flame, add 20 cc. of $AgNO_3$ solution, and then 30 cc. of the persulfate solution. Let the solution stand on the steam bath until it has developed a full permanganate color and no bubbles can be seen to come off when the flask is given a whirling motion. Cool to below 25° C., and titrate with the standard arsenite solution to the disappearance of the pink color.

to read as follows:

Use 1 g. of the sample if the manganese is not over 0.2 per cent. For a higher manganese content adjust the size of sample so that it will not contain more than 0.002 g. of manganese. Place it in a 250-cc. Erlenmeyer flask with 30 cc. of the Acid Mixture and heat until solution is complete. Boil until oxides of nitrogen are expelled. Dilute to 100 cc. with boiling-hot water, add 20 cc. of $AgNO_3$ solution and 30 cc. of the persulfate solution, then remove to a moderately warm place to stand for a few minutes for complete development of the permanganic acid. Cool to below 25° C. and titrate with the standard sodium arsenite solution to the disappearance of the pink color.

Change the first paragraph under Notes from its present form: namely,

Large amounts (above 0.01 g. of manganese per 100 cc. of solution) of permanganic acid are unstable; the method can, however, be used with satisfaction for alloys containing high percentages of manganese by decreasing the size of the sample.

to read as follows:

Large amounts of permanganic acid are unstable; on that account samples which contain large amounts of manganese should have correspondingly small samples weighed out.

Under the Determination of Manganese, in the Analysis of Light Aluminum Alloys, replace the paragraphs "Solutions Required" and "Method" with the following:

Proceed as described under "Determination of Manganese" in the Analysis of Aluminum.

This sub-committee would like to call attention to the fact that the revision in the Standard Sodium Arsenite Solution involves a change of the factor for weight of manganese per cubic centimeter of solution from 0.00050 g. to 0.00035 g. It is recommended that wherever a similar factor occurs in other A.S.T.M. standard methods of chemical analysis of non-ferrous alloys that a corresponding change be made.

Sub-Committee IX on Nomenclature of Metals and Alloys (E. E. Thum, chairman).—This sub-committee reported an examination during the past year into the question of changing the name of "spelter" to that of "slab zinc." As a result of several discussions within the sub-committee and of a questionnaire sent out to a number of producers and users of zinc, it is recommended that in the Standard Specifications for Spelter (B 6 - 18),[1] and wherever the word "spelter" appears in the standards of the Society it should be replaced by the expression "slab zinc (spelter)." This is believed to be a change in form only and not of substance, and hence it requires no action other than this recommendation by the committee.

Sub-Committee XIV on Silver and Gold Solders (R. H. Leach, chairman).—The development of the automotive and electrical industries and the extensive use of non-ferrous alloys and stainless steel has awakened very great interest in the commercial use of silver solder. With the large number of different formulas which can now be obtained from various sources a great deal of confusion exists among the users concerning the composition which should be purchased. The Specifications for Silver Solders were accordingly prepared by the committee as appended hereto,[2] which it is believed will be of appreciable value to the industry. These are based on the experience of the members of the sub-committee, the personnel of which is quite representative.

Sub-Committee XV on Die-Cast Metals and Alloys (H. A. Anderson, chairman).—This sub-committee is now engaged in a very comprehensive series of cooperative tests on both aluminum-base and zinc-base die-castings. These tests are well under way and are considered necessary as a preliminary step before standardization work in this field can be initiated. The report of the sub-committee is appended hereto. This report includes a statement prepared by Sam Tour dealing with the nature, production and uses of die-casting. A second statement is also included prepared by E. V. Pannell covering die-casting practices in Europe.

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[1] 1927 Book of A.S.T.M. Standards, Part I, p. 524.

[2] See p. 774.—ED.

At a special meeting of the Advisory Committee, Mr. Paul D. Merica, who has served Committee B-2 for many years as secretary, presented his resignation. This was regretfully accepted, and a vote of appreciation unanimously adopted. William Campbell was re-elected chairman, and E. E. Thum was elected secretary.

This report has been submitted to letter ballot of the committee, which consists of 115 members; 54 members returned their ballots, of whom 49 have voted affirmatively, none negatively, and 5 have marked their ballots "not voting."

Respectfully submitted on behalf of the committee.

WILLIAM CAMPBELL,
Chairman.

E. E. THUM,
Secretary.

EDITORIAL NOTE

The proposed Specifications for Fire-Refined Copper Other than Lake; for Seamless Copper Tubes; for Sand Castings of the Alloy: Copper 80 per cent; Tin 10 per cent; Lead 10 per cent; and for Silver Solders were accepted for publication as tentative and appear on pages 763, 778, 766 and 774, respectively.

The proposed revisions of the Standard Specifications for Free-Cutting Brass Rod for Use in Screw Machines; for Naval Brass Rods for Structural Purposes; for Bronze Bearing Metal in Ingot Form; and Methods of Chemical Analysis of Manganese Bronze were accepted for publication as tentative and appear on pages 1119, 1120, 1117 and 1120, respectively.

The Tentative Specifications for Brazing Solder; for Aluminum Bronze Castings; for Composition Brass or Ounce Metal Sand Castings; for Yellow Brass Sand Castings for General Purposes; for Bronze Castings in the Rough for Locomotive Wearing Parts; and for Car and Tender Journal Bearings, Lined, were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on September 1, 1928, and appear in the 1928 Supplement to Book of A.S.T.M. Standards.

The Tentative Specifications for Sand Castings of the Alloy: Copper 88 per cent; Tin 8 per cent; Zinc 4 per cent; and for Steam or Valve Bronze Sand Castings were approved at the annual meeting as revised by the committee and were subsequently adopted as standard by letter ballot of the Society on September 1, 1928, and appear in their revised form in the 1928 Supplement to Book of A.S.T.M. Standards.

The proposed revisions of the Tentative Methods of Chemical Analysis of Aluminum and Light Aluminum Alloys were accepted. The tentative methods in their revised form appear on page 782.

The proposed Specifications for Brass Ingot Metal, Graded and Ungraded, for Sand Castings were accepted for publication as tentative to supersede the present standard specifications which were accordingly withdrawn. The new tentative specifications appear on p. 770.

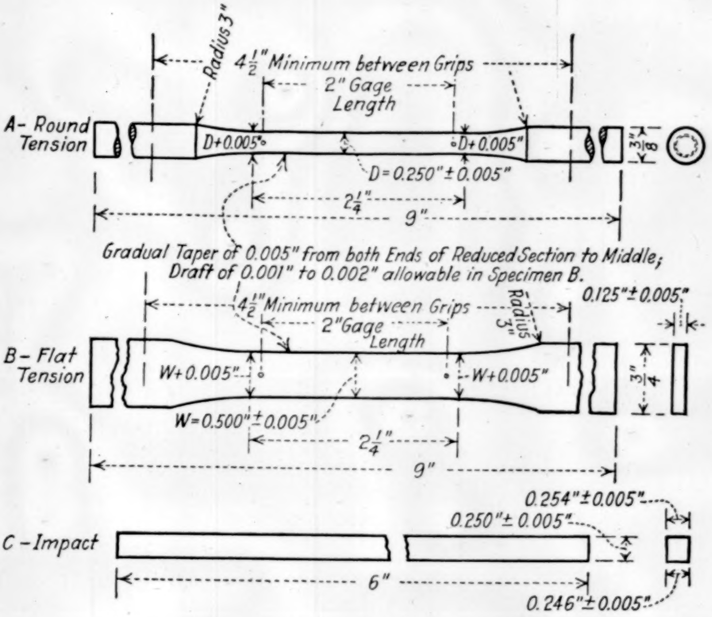
REPORT OF SUB-COMMITTEE XV ON DIE-CAST METALS AND ALLOYS

An investigation of die-cast metals and alloys was undertaken because of the desire of certain companies contemplating extensive use of die-castings to have available dependable information regarding the properties to be expected from the different alloys in use. The largest producers of die-castings, as well as certain consuming and general interests, have entered enthusiastically into this cooperative investigation and have made large contributions in materials or tests and other committee activities. The extent of the investment of those cooperating may be better appreciated when it is realized that 55,000 specimens have been prepared and distributed among the cooperating laboratories and that these laboratories have already reported the results of their tests of some 10,000 specimens.

The nature, production and uses of die-castings are summarized in a paper by Sam Tour appearing as Appendix I to this report. There are different types of die-casting machines and the various manufacturers have built up their business around certain groups of alloys. The result is that when asked to bid on the delivery of a certain part from a certain alloy, a manufacturer may request permission to substitute the alloy, which, on the basis of his operating experience, is best suited for the production of the casting in question. Without knowledge as to the mechanical and corrosion-resistant properties of the different alloys, and lacking information as to the extent to which these properties are affected by the type of casting equipment, the purchaser is at a loss to determine whether to permit a change from an alloy which his experience has shown to be satisfactory.

The committee decided to evaluate the properties of the most commonly used die-casting alloys in the form of round and flat tension and square impact specimens including specimens from as many producers as possible. The design of the specimens shown in Fig. 1 was based on the best shapes obtainable from a testing standpoint and also, from a die-casting standpoint, so as to represent various ratios of perimeter to cross-section, inasmuch as the strength of die-castings is influenced largely by this factor. A study of aluminum-base alloys was undertaken initially, and subsequently the investigation has been extended to include zinc-base alloys.

In undertaking this study of die-cast test specimens the committee realized that the properties of the metal in different parts of a


Radius 3"
4½" Minimum between Grips
2" Gage Length
A- Round Tension
D+0.005"
D+0.005"
3/8"
D=0.250" ± 0.005"
2¼"
9"
Gradual Taper of 0.005" from both Ends of Reduced Section to Middle;
Draft of 0.001" to 0.002" allowable in Specimen B.
4½" Minimum between Grips
Radius 3"
0.125" ± 0.005"
2" Gage Length
B- Flat Tension
W+0.005"
W+0.005"
3/4"
W=0.500" ± 0.005"
2¼"
9"
0.254" ± 0.005"
0.250" ± 0.005"
C -Impact
6"
0.246" ± 0.005"

The three Specimens shown to be cast in Die Plate, parallel to each other at 2" Center to Center.

Specimens to be gated at one End (on Midline of Center Specimen); no Ejector Pins on Reduced Sections; Pin Marks on Ends to be flush or low.

Specimens to be removed from Dies as soon as cast, cooled-adjacent in Wooden Box with Gates attached.

Gates to be sawed off before Shipment but Fins to be removed in Testing Laboratory.

Each Specimen to be marked with Number of Alloy, Roman Numerals (I to XXI) and Initials of Manufacturer (Insert) and tagged with Date of Casting.

Specimens A and B for Tension and C for Izod or Charpy Impact.

Hardness Tests to be made on Ends of Specimen-B-using Rockwell Scale "E" (1/8" Ball, 100 Kg. Load, Red Figures). Test on 3/16" Diam. Anvil; remove Major Load as soon as fully applied.

Low Capacity Impact Machines of type suitable for Die Casting Tests are described in A.S.T.M. Proc. 1926, II 634 ff.

Minimum Number of Specimens to be tested: Tension and Impact, 5 of each Type; Rockwell, 3 Readings on each Flat Specimen. Report Rockwell Readings for Gate (thick Fin) and vent Ends ***separately.***

FIG. 1.—Test Specimens for Die-Casting Alloy Investigation.

die-casting will vary depending upon the cross-section, the method of gating and other casting conditions, and therefore no test specimen can give a true measure of the strength of a finished part. It was also recognized that the data obtained from a limited number of lots of specially prepared material could not be considered as necessarily representing the minimum properties that might be obtained in normal commercial production, and this fact must be taken into consideration in the formulation of specifications. However, it was agreed that a study of the various alloys was essential before an attempt is made to prepare specifications and that such a study would permit comparison between alloys and perhaps indicate the extent to which the results for a given alloy are influenced by the type of die-casting equipment and by the operating practice.

Six manufacturers agreed to make up dies to produce the three forms of test specimen which were designed by the committee and to supply each of the cooperating testing laboratories with a set of specimens for each of twelve aluminum-base alloys selected as representing all of the different types in common commercial use. All of the producers, except one, made up their dies, and furnished test specimens as agreed. Six producers have promised similar cooperation in the case of the six commercial zinc-base alloys which the committee has more recently undertaken to investigate. Twelve testing laboratories agreed to cooperate by furnishing physical or chemical test data on certain or all of the manufacturers' specimens. The cooperating producers and testing laboratories are listed below:

COOPERATING PRODUCERS

(All furnishing complete sets of specimens, except as noted)

1. Aluminum Co. of America (through the U. S. Aluminum Co., formerly The Aluminum Die Casting Corporation), Garwood, N. J.
2. Doehler Die Casting Corporation, Batavia, N. Y.
3. General Electric Co., River Works, West Lynn, Mass.
4. Stewart Die Casting Corporation, Chicago, Ill.
5. Westinghouse Electric and Manufacturing Co., East Pittsburgh, Pa.
6. Franklin Die Casting Corporation, Syracuse, N. Y.
7. The Newton Die Casting Corporation, New Haven, Conn.
8. The New Jersey Zinc Co., Palmerton, Pa.
9. The Allied Die-Casting Corporation, Long Island City, N. Y.

COOPERATING TESTING LABORATORIES

1. Aluminum Co. of America, New Kensington, Pa.
   Physical tests and chemical analyses of all lots.
2. Bell Telephone Laboratories, Inc., New York City.
   Physical tests (including Shelf Life Aging) on all lots.

3. General Electric Co., River Works, West Lynn, Mass.
   Physical tests and chemical analyses on own produced specimens.
4. General Motors Corporation, Detroit, Mich.
   Physical tests on all lots.
5. The Hoover Co., North Canton, Ohio.
   Physical tests on all lots.
6. Stewart Die Casting Corporation, Chicago, Ill.
   Physical tests and chemical analyses on own produced samples.
7. U. S. Army Air Corps, Wright Field, Dayton, Ohio.
   Physical tests on all lots.
8. U. S. Navy Yard (Material Branch), Washington, D. C.
   Physical tests on all lots.
9. Western Electric Co., Hawthorne, Chicago, Ill.
   Chemical analyses on all lots and physical tests on part.
10. Westinghouse Electric and Manufacturing Co., East Pittsburgh, Pa.
    Physical tests and chemical analyses on all lots.
11. White Motor Co., Cleveland, Ohio.
    (C. W. Simpson representing S.A.E. on sub-committee).
    Physical tests on all lots.
12. The New Jersey Zinc Co., Palmerton, Pa.
    Physical tests and chemical analyses on all zinc-base alloys.
13. The National Lead Co., Brooklyn, N. Y.
    Physical tests and chemical analyses on certain zinc-base alloys.

The test data are being accumulated and reported to the committee at a gratifying rate. However, in view of the fact that the incomplete data at present available might be misleading and unfair to certain producers, the sub-committee is not reporting any of these test data until next year.

In order to conduct a cooperative investigation of this type with information being incorporated into a joint report on specimens from various producers tested in various laboratories, it was found desirable to standardize certain variables. These included the nominal compositions of the alloys (Appendix II), the size and shape of the specimens, Fig. 1, the method of preparation (without reference to specific die-casting machines), Fig. 1, and standard procedures for the tension, hardness and impact tests and for chemical analyses (Appendix III). A form of test record was prepared to facilitate the conduct of the test according to the procedure agreed upon (Appendix III).

The standardization of the tension testing procedure involved the design of suitable specimens and recommendations regarding the capacity and alignment of testing machines suitable for making strength measurements on the small cast specimens. The common forms of hardness testing machines were found to be unsuited for measurements on die-castings, so the committee worked out a combination of load and penetrator which appeared to give useful results in tests on the Rockwell Hardness Machine. This test has been subsequently standardized by the manufacturer of the testing machine and included as a recommended test for certain classes of non-ferrous alloys (Appendix IV).

The committee felt the need of information regarding the relative brittleness of die-casting alloys and is attempting to develop a suitable impact test. Some eight or ten low-capacity impact machines have been made available for the use of the committee and a considerable amount of information is being collected which it is proposed to place at the disposal of the technical committee on impact testing, of Committee E-1 on Methods of Testing, in its standardization activities.

Information is also needed regarding the relative corrosion resistance of the various die-casting alloys. Inasmuch as no considerable increase in the expense for preparation of specimens was entailed in accumulating a sufficient supply for such corrosion tests as might later be agreed upon, a lot of specimens from each producer equal to the aggregate quantities supplied by them to the cooperating laboratories was prepared and stored at the U. S. Bureau of Standards. At the invitation of the sub-committee, Committee B-3 on Corrosion of Non-Ferrous Alloys has agreed to expose die-cast specimens on its racks in connection with the atmospheric exposure test plan for non-ferrous alloys in general. Sub-Committee XV has agreed to cooperate in raising the funds being solicited by Committee B-3 and to assume the responsibility for the physical tests used for evaluating the extent of the atmospheric corrosion. Sub-Committee XV is also conducting shelf life aging tests which give promise of yielding interesting age hardening characteristics of the aluminum-base alloys and contemplates steam corrosion tests as well as normal aging and atmospheric exposure tests of the zinc-base alloys.

Among its other activities, the sub-committee had had prepared by one of its members and has circulated a summary of die-casting practices in Europe (Appendix V). The report was based in part on personal observations of the author during the past summer abroad. It shows a comparatively limited development of "pressure die-casting" in Europe, because of the relatively small quantities of goods produced and states that "die-casting" in Europe usually refers to "permanent mold" casting.

To summarize, the sub-committee has completed its cooperative tests on about 10,000 of the 50,000 aluminum-base test specimens which it prepared and distributed to its members, has exchanged test data among its members in the form of averages and average deviations of physical properties as well as chemical analyses, has work under way on the balance of the specimens, has lined up a program for conducting its corrosion tests in cooperation with Committee B-3, and has agreed upon, and secured promises of similar cooperation in, its zinc-base program involving about one-half as much testing as for the aluminum-base alloys. The sub-committee anticipates that its data, together with tentative specifications on aluminum-base alloys, will be presented to Committee B-2 one year from now, and similar completion of its work on the zinc-base program in about two years.

H. A. ANDERSON,
Chairman.

P. V. FARAGHER,
Secretary.

APPENDIX I

NATURE, PRODUCTION AND USES OF DIE-CASTINGS

By Sam Tour[1]

Definition:

The term "die-casting" as used by engineers in this country applies to metal castings made by forcing molten metal under pressure into a metallic mold or die. The term therefore does not include castings poured by gravity into a metallic mold or die. Such castings are frequently called die-castings in Europe but in this country are referred to as "permanent mold castings." The better name for "die-castings" is therefore "pressure die-castings."

Process:

The pressure die-casting process requires:

1. A machine capable of delivering molten metal under pressure to a die.
2. A metallic mold or die to receive the molten metal.
3. A suitable alloy which will function in the machine, form in the die and will yield a casting with the desired physical properties.

The result of the proper combination of the above three essentials is a finished or practically finished casting of sharp detail, checking to very close dimensional tolerances, requiring little or no machining, rapidly producible in large quantities. The process often makes possible the use of much thinner walls than can be cast by any other method. It is usually not economical nor practical to pressure die-cast parts which can be produced by a sand casting process and used without machining.

Casting Machines:

The type of casting machine used is dependent to a large extent upon the type of alloy to be cast. Alloys of lead, zinc, tin and aluminum base are regularly die cast. Brasses, bronzes and the like are not pressure die-cast. For the lead, zinc and tin-base alloys a machine which delivers molten metal by means of a plunger working in a cylinder may be and is very largely used. For aluminum-base alloys the plunger principle does not prove practical due to the solvent action of molten aluminum on practically all commercial metals and therefore for these alloys the machine delivers its molten metal by means of compressed air applied in a properly designed container. The temperatures and pressures in the machine necessitate the use of ferrous alloy containers, due to the lack of any other known satisfactory material. Cast iron is generally used as it is more resistant to molten aluminum than steel, although it is quite rapidly attacked. A certain amount of iron is absorbed depending upon the nature of the alloy and the temperature and speed at which the die-cast parts are made.

Dies:

The kind of metallic mold or die used to produce a given part is of course dependent to some extent upon the type of casting machine in which it is to be used. Several other factors are important however. In producing lead, tin and zinc-base castings the casting temperatures are not high and dies are constructed of simple steels not requiring heat treatment. In making aluminum-base castings, however, casting temperatures are such as to require special die steels very carefully heat treated to obtain maximum life. Dependent upon the quality of castings required, the dies may be of single or multiple impressions. The cost of building a die and producing castings is materially affected by the degree of accuracy required in the finished casting. The surface finish required on castings is also a considerable factor in the construction of the die and in the cost of castings. (The American Society for Steel Treating issued Data Sheet N41 in January, 1928, covering "Tentative Recommended Practice for the Heat Treatment of Dies for Die-Casting.")

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[1] **Metallurgist,** Doehler Die Casting Co., Batavia, N. Y.

Cost of Castings:

It has been stated that castings cannot be considered as practical die-casting jobs in lots of less than 10,000. This is entirely wrong. As a general rule, the pressure die-casting process is most economical where the elimination of machining and finishing operations is possible. The process does not compete with simple screw-machine parts, sheet metal stampings or simple sand-cast parts requiring little or no machining or finishing. The number of castings to completely absorb the initial cost of the die is therefore dependent upon the amount of costly machining and finishing operations eliminated by the use of a pressure die-casting. Very often this saving is so great that even a few hundred or a thousand castings required are sufficient to justify the construction of a die.

Structure:

The typical structure of a pressure die-casting as shown by fracture has a very dense close-grained outer surface. The structure tends to become coarser as the distance from the outer surface increases, and at the center of the section there occurs a somewhat porous condition. This condition is the natural result of the method of production and the shrinkage of the metal from the liquid to the solid state. The dies are maintained at a temperature well below the melting point of the alloy. The cavity to form the casting is filled with molten metal very rapidly, and immediately the moltel metal is chilled by the comparatively cold die surfaces. The natural shrinkage from the liquid to the solid state of the alloy being used must therefore appear at the center of the section where the chilling effects from opposite surfaces meet. Due to the rate of cooling, no back feeding, etc., such as is practiced in sand casting, etc., is possible.

Porosity due to this shrinkage must be present and no method is known whereby it can be eliminated. However the disadvantages of this internal porosity are somewhat compensated for by the very fine-grained dense outer surface which increases tensile strength, improves polishing properties and provides a wearing surface far superior to any casting made from the same alloy by any other process. In fact, the actual tensile strength of a given section in an alloy when pressure die cast is greater than when cast by gravity in permanent molds and is very much greater than when sand cast.

Blowholes in pressure die-castings are distinctly different from porosity due to metal shrinkage. As the molten metal is forced into the die the air in the die must be driven out. If some of it remains in the die it may be completely surrounded by metal and appear in the casting as a blowhole. By careful die design, venting and gating it is usually possible to minimize and in many cases entirely eliminate this trouble. Each differently shaped part being cast presents its own problems in this respect.

To the extent to which it is possible for molten metal to dissolve gases in greater amounts than it can retain upon solidification, the "gassing" of metal produces blowholes. This feature is minimized in pressure die-castings due to the extremely rapid rate of solidification, which tends to increase the amount of gases which the metal can retain in the solid state. Nevertheless, it has a direct bearing upon the amount and nature of the blowholes appearing in the finished casting. Blowholes from this source are controlled by the use of proper alloys and proper melting and casting conditions.

Production:

The present estimated annual production of pressure die-castings in the United States is from ten to twelve million pounds of aluminum-base castings and from fifty to sixty million pounds of zinc-base die-castings. It is evident, therefore, that these types of castings are being very widely used.

Uses:

Pressure die-castings are used in automobile parts such as steering wheel spiders, carburetor parts, oil purifier parts, oil pumps, fans, water pumps, electric starters, spark and throttle control parts, windshield wipers, instrument boards, speedometers, hand rests, interior trim handles, cowls, etc. They are used extensively in vacuum cleaners, washing machines, typewriters, check writers, adding machines, calculating machines, small motors, magnetos, radio condensers, radio frames, loud speakers, telephones, vending machines, instrument parts, instrument cases, small machine parts, ornamental parts, furniture, cooking utensils, and electric refrigerators.

Production Practice in Alloys:

Pressure die-castings are produced in zinc, aluminum, lead and tin-base alloys. In general, the producers purchase their raw materials and mix their own alloys. The usual practice has been for the consumer or purchaser of pressure die-castings to designate which type of alloy was desired, to supply information as to service requirements of the finished castings and to depend upon the producer to select the particular composition in the type specified which, in the light of his experience, would result in the best castings for the purpose. Some parts require strength and rigidity, some ductility, some polishing properties, some machining qualities, some corrosion-resistant qualities, etc. It is manifestly absurd to assume that any one zinc alloy or aluminum alloy or any other alloy will meet the service requirements of all pressure die-castings.

On the basis of his experience, each producer of pressure die-castings has adopted a number of standard alloys which will meet most service requirements. As the standard alloys of each producer are based upon his individual experience and his individual practice and equipment, it is obvious that the standard alloys of one producer are somewhat different in composition from the standard alloys of another producer. The producers are usually willing to depart from these standards when necessary, in order to better meet the customer's requirements.

APPENDIX II

LIST OF ALLOYS AGREED ON FOR DIE-CASTING INVESTIGATION, WITH NOMINAL COMPOSITIONS DESIRED

Aluminum Base Alloys

Number[a]	Copper, per cent	Silicon, per cent	Nickel, per cent	Iron, per cent	Aluminum, per cent
I	4	..	..	1½ to 2	Balance(94)
II	10	..	..	1½ to 2	Balance(88)
III	14	..	..	1½ to 2	Balance(84)
IV	..	5	..	1½ to 2	Balance(93)
V	..	13	..	1½ to 2	Balance(85)
VI	2	3	..	1½ to 2	Balance(93)
VII	4	5	..	1½ to 2	Balance(89)
VIII	1½	¾	2¼	1½ to 2	Balance(94)
IX	4	1½	4	1½ to 2	Balance(89)
X	..	2	5	1½ to 2	Balance(91)
XI	2	8	..	1½ to 2	Balance(88)
XII	8	1	..	1½ to 2	Balance(89)

Zinc Base Alloys

	Copper, Per Cent	Aluminum, Per Cent	Magnesium, Per Cent	Tin, Per Cent	Zinc, Per Cent	Grade of Zinc Based on A.S.T.M. Specification, B 6–18
XIII	5.0	0.25	...	...	Balance(94.75)	High Grade
XIV	3.0	4.0	...	...	Balance(93.0)	High Grade
XV	3.0	4.0	0.1	...	Balance(92.9)	High Grade
XVI	3.0	4.0	0.1	...	Balance(92.9)	Special High Grade[b]
XVII	3.0	3.0	0.3	...	Balance(93.7)	High Grade
XVIII	3.0	0.5	...	6.0	Balance(90.5)	Prime Western
XIX	2.0	4.0	0.1	...	Balance(93.8)[d]	Special High Grade[b]
XX	3.0	4.0	...	...	Balance(93.0)	Special Grade[c]
XXI	3.0	4.0	0.1	...	Balance(92.9)	Special High Grade[e]

---

[a] This identification number and the manufacturer's mark should be cast on each specimen.

[b] Special grade, lead and cadmium together, permissible maximum, 0.06 per cent; tin, none; zinc, minimum 99.94 per cent.

[c] Slab zinc analyzing at least 99.75 per cent zinc.

[d] Containing nickel 0.02 per cent in addition.

[e] Special grade, lead and cadmium together, permissible maximum, 0.02 per cent; tin, none; zinc, minimum, 99.98 per cent.

1. The composition shall be controlled by analyses of specimens selected at random.

2. The aluminum-base alloys should preferably be free from manganese and magnesium (permissible maximum on each, 0.05 per cent); the zinc-base alloys should be made of the specified or a higher grade of zinc, 99-per-cent aluminum, straits tin and electrolytic or lake copper.

3. Three hundred sets of each of Specimens A, B and C, Fig. 1 of the report, are to be furnished by each producer in each of the 12 aluminum-base alloys, and 500 sets of each for the zinc-base alloys (the additional sets being required for accelerated corrosion tests).

APPENDIX III

STANDARD TESTING PROCEDURE

Types of Tests and Number of Specimens:

Tension.—Determining tensile strength in lb. per sq. in. and elongation, per cent in 2 in.

Testing machine to be of proper sensitivity; recommended head speed 0.2 in. per minute, maximum. Grips having self-aligning features should be used.

Dimensions for computing cross-section to be taken at smallest area.

Average diameters around bar for round specimens.

Gage marks for elongation should not damage specimen.

Minimum number of specimens to be tested, 5 flat and 5 round of each alloy.

Hardness.—Determining Rockwell "E" values, 100 kg. load, $\frac{1}{8}$-in. diameter ball penetrator, reading *red* figures, maximum time for application of full load and its removal, 8 seconds. Number of tests, 2 readings each on gate end and vent end of flat specimens, averaged separately (also Brinell or Scleroscope readings if desired).

Impact.—No agreement as yet on procedure, but certain results reported, using following procedure:

Charpy.—Span, 40 mm., specimens tested without notches. Thickness taken normal to plane of flash fins and specimens broken in that direction, three 2-in. specimens from each 6-in. sample. Recommended capacity of Charpy machine, 12 to 15 ft. lb.

Izod.—Striking distance, 0.87 in., note whether gate or vent end up.

Chemical Analyses.—(by certain laboratories only).

Analyses of aluminum-base alloys to be made in accordance with A.S.T.M. Tentative methods of Chemical Analysis of Aluminum and Light Aluminum Alloys (B 40 – 27 T)[1]. For aluminum-base alloys, determine copper, silicon, nickel, zinc, iron, manganese, calcium, magnesium, and aluminum by difference.

For zinc-base alloys, determine zinc, copper, aluminum, magnesium, tin, lead, cadmium, iron, antimony, and manganese. The New Jersey Zinc Co. recommends the wet method of analysis for all elements in zinc-base except that magnesium, cadmium and low tin contents be determined spectroscopically and zinc by difference.

In the case of aluminum-base alloys, sample by drilling through middle of both ends of five flat specimens selected at random. In the case of the zinc-base alloys, break up 20 specimens into small pieces to provide 1500 g. of sample for analysis.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, **Part I**, p. 740 (1927); **also** 1927 Book of A.S.T.M. Tentative Standards, p. 152.

For check on analytical methods use Bureau of Standards Standard Samples.

Test Records.—Date all test data and furnish supplementary information.

Duplicate copies of data with summary to be furnished to subcommittee chairman. Physical test records may conveniently be taken on "Die-Cast Test Record Forms," prepared by Bell Telephone Laboratories, Inc., appended hereto.

TEST RECORD

DIE-CAST METALS AND ALLOYS

TEST DATE

LAB'Y

MATERIAL .... COMM. ALLOY NO. .... SPECIMENS PER SKETCH ES-406597

PRODUCED BY .... AT .... MFRS. MARK ....

DATE DIE CAST .... DATE RECD. BY LABORATORY ....

TENSILE TESTING MACHINE: MAKE AND CAPACITY .... RANGE USED ....

IMPACT TESTING MACHINE: TYPE, MAKE AND CAPACITY .... FT. LB.

HARDNESS TESTING MACHINE ....

TENSION AND HARDNESS TEST RECORD

SPECIMEN	THICKNESS OR DIAMETER, IN.	WIDTH, IN.	AREA, SQ. IN.	ROCKWELL "E" SCALE $\frac{1}{8}$-IN. BALL, 100-KG. RED FIGURES		MAXIMUM LOAD, LB.	TENSILE STRENGTH, LB. PER SQ. IN.	AVERAGE DEVIATION, PER CENT	ELONGATION IN 2 IN., PER CENT	FRACTURE LOCATION, PER CENT BLOW-HOLES
				VENT	GATE					
FLAT										
1										
2										
3										
4										
5										
AVER.										
ROUND										
1										
2										
3										
4										
5										
AVER.										

TYPE OF GRIPS USED .... RECORDER .... CHECKER ....

SPEED OF PULLING HEAD, IN. PER MIN. ....

IMPACT TEST RECORD

SPECIMEN	THICKNESS, IN.	WIDTH, IN.	AREA, SQ. IN.	IZOD, FT. LB.	CHARPY, FT. LB.	NOTES
1						
2						
3						
4						
5						
AVER.						

RECORDER .... CHECKER ....

NOTES

REPORTED BY ....

APPENDIX IV

SPECIFICATIONS FOR ROCKWELL SPECIAL "E" SCALE

Special "E" scale is intended for testing certain soft metals or alloys, the makers and users of which find the $\frac{1}{8}$-in. ball penetrator and 100-kg. major load the preferable testing combination. Whereas the "B" Scale with $\frac{1}{16}$-in. ball penetrator and 100-kg. major load and the "C" Scale with the Sphero-conical diamond Brale penetrator and 150-kg. major load are the only standard Rockwell Scales, a special "E" Scale has been used experimentally by Sub-Committee XV of Committee B-2 of the American Society for Testing Materials.

Certain makers and users of die castings have been employing the combination of $\frac{1}{8}$-in. ball penetrators and 100-kg. major load and have found it useful. We are recognizing this special "E" Scale and printing this sheet in order to give them present help towards uniformity.

1. *Penetrator.*—$\frac{1}{8}$-in. steel ball; to be replaced by new ball from time to time and behavior of penetrator to be checked against "E" scale test blocks.

2. *Loads.*—The minor load to be 10 kg. as applied by all Rockwell Testers. The major load to be 100 kg.

3. *Dial Readings.*—After minor load has been applied the dial to be set so that pointer reads B-30, *i.e.*, so that pointer stands at the scale division marked "Set" on the dial. Final hardness readings to be taken according to the *red* numerals of the dial and in all notations and data the letter "E" to be substituted for red letter "B" that appears on the dial. The black numerals on the dial to be ignored.

4. *Cushioning and Support.*—Because the "E" Scale is employed for comparatively soft metals it is important to see that the machine during tests is not subjected to vibration or operated so rapidly as to cause jarring or shock, and for like reason the piece tested should rest upon a supporting area $\frac{3}{16}$ in. in diameter, or larger.

5. *Minor Load.*—The specimen should be elevated to gently contact the penetrator and in elevating further to apply the minor load this action should be under such control that without retreating or lowering the specimen the pointer rests within 5 divisions of vertical at the end of the last revolution of pointer.

6. *Overhang.*—The test specimen shall be well supported to prevent errors due to overhang of the specimen. The Vari-Rest supplied as an accessory is convenient for this purpose if specimens are long.

7. *Minimum Thickness.*—Specimens with a hardness of over E-60 may be tested down to a thickness of $\frac{1}{8}$ in; softer specimens should be at least $\frac{3}{16}$ in. thick. The actual thickness should be reported if the specimen is thinner than these limits.

8. *Speed.*—The dash pot should be adjusted so that the handle revolves in about 5 seconds when no specimen is in place. In making a test, the major load should be removed within 2 to 3 seconds after the retarding finger breaks away from the weight lever.

9. *Adjustments.*—Index lever adjustments should be looked to and all other standard directions should be observed.

APPENDIX V

NOTES ON EUROPEAN DIE-CASTING PRACTICE

BY E. V. PANNELL[1]

INTRODUCTION

Die-castings of the type commercially developed by a few firms in America are produced in England under the name "Pressure Castings"; in Germany they are termed "Spritzguss" and "Fertigguss"; and in France, "Moulage sous Pression." The phrase "die-casting" in Europe generally includes castings poured by gravity, in other words "permanent mold castings." In Great Britain die-castings proper are produced by twelve or more concerns. The art has developed from the older one of type founding and a number of the die-casters are still type founders, all their work being done in tin, lead, and zinc-base alloys. An estimate of the heavy metal die casting production in Great Britain is from three to five million pounds per year, but it is difficult to arrive at an accurate figure.

MACHINES FOR HEAVY ALLOYS

The machines used are in some cases quite primitive, being entirely manual in operation. A number of these are of Swedish design mostly of the plunger type, and either vertical or horizontal in action. A light semi-manual machine of Swedish design using air at 16 to 40 lb. per sq. in. pressure is also in use. This has a vertical cylinder and plunger set in the middle of the metal pot, the metal being shot horizontally. For small castings the machine is countershaft driven, producing up to thirty per hour of a limiting weight of 4 oz. With manual operation much heavier castings can be poured. An English machine known as the "Invincible" is designed with the customary plunger and rack and pinion feed and a die preheating chamber. It will operate with metals up to a melting point of 930° F. The metal pot holds 55 lb. of zinc-base alloy.

Alloys: Zinc and Lead Base:

A wide variety of zinc, tin and lead alloys are in use. A. H. Mundey quotes the following representative mixtures as used by one of the most important die casting concerns.

ZINC ALLOY (ALLOY A)		LEAD ALLOY (ALLOY B)	
Zinc	85 per cent	Lead	80 per cent
Tin	8 "	Antimony	15 "
Copper	4 "	Tin	4 "
Aluminum	3 "	Copper	1 "

Mundey states that a small percentage of aluminum prevents the zinc alloy from galvanizing the die, but an excess will not only lead to unsound castings but also corrode the die. Dies are quite commonly of mild steel, sometimes with alloy steel cores and inserts. Some British die-casters claim that the swelling of zinc-alloy castings is due to the presence of aluminum in more than 1 per cent, especially where tin is also present.

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[1] Consulting Engineer, The British Aluminium Co., Ltd., New York City.

N. F. Budgen quotes the following compositions as used in England.

ZINC ALLOY (ALLOY C)

Zinc	87.5 per cent	Tensile Strength	16 000 lb. per sq. in.
Tin	8 "	Elongation	2 per cent
Copper	4 "	Brinell Hardness	65
Aluminum	0.5 "		

TIN ALLOY (FOR BEARINGS)

	ALLOY D	ALLOY E	
Tin	92.0 per cent	89.0 per cent	Tensile Strength 6000 lb. per sq. in.
Copper	1.8 "	4.0 "	
Antimony	6.2 "	7.0 "	

LEAD ALLOY (LIGHT BEARINGS, COFFIN TRIMMINGS, ETC.)

	ALLOY F	ALLOY G	ALLOY H	ALLOY J
Lead, per cent	83	90	80	80
Tin, per cent	0	0	10	5
Antimony, per cent	17	10	10	15

Another authority, E. J. Bedford, mentions the use of the following five alloys of the zinc base group.

	ALLOY K	ALLOY L	ALLOY M	ALLOY N	ALLOY O
Zinc, per cent	89	86.25	82.75	83.0	88.0
Copper, per cent	11	11.00	3.45	10.0	6.0
Aluminum, per cent	..	2.75	13.8	2.0	0.5
Tin, per cent	..	....	....	5.0	5.5

Bedford states that these alloys all melt at about 500° F. Aluminum is introduced for increased fluidity and density of castings though the proportion in alloy M would seem unusually high.

LIGHT ALLOY PRACTICE

Turning to the more advanced form of the art, the production of light alloy die castings, the English situation does not possess the potentialities of the American at an earlier stage for the reason that castings from a given pattern are called for in relatively small numbers. The higher all around cost of aluminum die castings is of course occasioned not only by the cost of metal but by the more expensive material and workmanship on the dies and greater overhead charges on machines and compressed air equipment. Since an order will be placed in thousand lots, where in the United States it would be ten times as great, the die charges in the former case will be nearly ten times as high. In this country there is an annual production of about four and one-half million automobiles from approximately forty-five significant makers, an average production of one hundred thousand. In Great Britain some one hundred makers produce one hundred and fifty thousand cars, an average of fifteen thousand of a given design. Standardization is therefore carried to a much smaller degree than in America and the great diversity of parts called for by the trade is best served by the use of permanent mold castings for which there is a large and increasing market. George Mortimer discusses the situation as follows:

> "There is, in fact, little room for comparison between the outlay on a gravity mould and that on the highly-developed die of a pressure machine. The former is justified on orders for a few hundreds only. For the same casting a pressure die would seldom be justified for orders of as many thousands, whilst the great pressure die casting industries were in fact largely built up on orders running into the region of millions of castings from one fixed design.
>
> "It is mainly for this reason that we in this country, lacking the demand for castings in vast numbers to one design, have tended to develop the undoubted usefulness of the simple gravity mold; whilst Americans, with their immense internal markets and their genius for quantity production, have brought the process of pressure casting to a very high art. There are wireless and telephone parts, household and automobile fittings required in this country in quantities which well justify the initial outlay on the pressure system. In few cases, however, do the quantities called for approach the numbers taken by the internal market of the United States; and the field, such as it is, would appear to be amply covered by the few firms in this country specializing in the process.
>
> "Pressure casting spells 'overhead,' not only in plant but in much specialized and patiently acquired experience; for the mere purchase of an up-to-date machine is probably the smallest step towards the economical production of pressure castings. Gravity casting is on the whole the more generally suited to the technical and economical requirements of industry in this country as at present constituted."

Air and Plunger Machines:

For these reasons, the entire annual production of light alloy die castings in Great Britain is probably not in excess of one and one-half million pounds. A similar tonnage is produced in Germany, and an appreciably smaller quantity in France. Among the machines in use for light alloy die casting are those well known in the United States, such as the Doehler, Stewart, Acme, Soss. In addition, a number of interesting designs come from Sweden. As is well known, the plunger type of machine is entirely superseded by the air pressure type in America wherever the melting point of the alloy is over 900° F. In Europe, however, there is a certain amount of prejudice against the air machine, no doubt on account of the relatively high cost of compressor plant for a small shop. It is also asserted that air leakage and the behavior of compressed air on the molten aluminum are a disadvantage. Lack of density in the castings is considered a serious demerit of the compressed air machine. In spite of its obvious drawbacks, therefore, there is an attempt to use the plunger machine for these alloys. According to E. J. Bedford, this is being done commercially. Obviously some method must be employed to protect the plunger. A Swedish firm has devised a machine of ingenious design which is used not only in Sweden but in Germany. The plunger operates vertically on molten lead held in a U-shaped container, the plunger being on one side of the U, the other communicating with the aluminum pot and the die. Molten lead takes the place of the plunger in contact with the aluminum. Unfortunately, although no lead-aluminum alloy is formed, a certain amount of the heavy metal is picked up and contaminates the casting. The U-pipe or siphon communicates with the bottom of the metal pot by an automatic valve and this valve being permanently immersed in molten metal is also prone to give trouble.

According to a German authority, A. Kaufman, a disadvantage attaching to the conventional gooseneck type of machine is the continual disturbance of the oxide film and a device which would tap the metal pot at the bottom is preferred. This is effected by a design of machine used in Germany in which the metal pot and the die are set side by side, and midway between them a vertical metal container of inverted siphon *J* form to which air pressure can be applied. The lower nozzle of the *J* is first applied to a valve at the bottom of the crucible and drawn full of metal. It is then swung around on a vertical axis, the nozzle applied to the die, and shot by air in the usual way. As a merit of this machine it is stated that silicon alloy can be held in the metal pot with a layer of salt undisturbed on its surface during the entire casting operation.

Light Alloys:

Light alloys for die casting are not very different from those used in American practice. N. F. Budgen, who has already been quoted as a British authority, gives the familiar number 12 alloy as representing the bulk of the die castings produced.

ALUMINUM ALLOY (ALLOY P)

Aluminum..................	92 per cent	Tensile Strength 20 000 lb. per sq. in Elongation, 1.5 per cent Brinell Hardness, 60
Copper....................	8 "	

The physical properties are derived from a test bar poured by gravity into an iron mold. Some die castings, according to Budgen, are heat treated, for which the following alloys are suggested.

	ALLOY Q	ALLOY R	
Aluminum....	95 per cent	88 per cent	Tensile Strength 34 000 lb. per sq. in. (treated)
Magnesium...	2 "	6 "	
Copper.......	3 "	6 "	

In addition to the foregoing, the addition of silicon to aluminum-base alloys is quite usual, also the use of a straight 6-per-cent silicon-aluminum mixture. Some sources of information state that light alloys containing zinc are in use, but it is doubtful whether they are used to any significant extent in spite of the general popularity of zinc alloys for other purposes. E. J. Bedford gives particulars of an alloy containing a relatively high proportion of silicon.

ALLOY S

Aluminum....................................	81.5 per cent
Silicon......................................	15.0 "
Copper......................................	3.0 "
Manganese..................................	0.5 "

F. A. Livermore quotes yet another mixture:

ALLOY T

Aluminum....................................	92 per cent
Copper......................................	7 "
Manganese..................................	1 "

Die steels are discussed by E. J. Bedford who recommends a chromium-vanadium composition for a production of 5000 to 8000 castings from a die, but states that 18,000 or more can be obtained from a tungsten steel die without serious checking.

CHROMIUM-VANADIUM STEEL	
Chromium	2.10 per cent
Vanadium	0.35 "
Carbon	0.40 "
Manganese	0.65 "
Silicon	0.10 "

TUNGSTEN STEEL	
Tungsten	18.00 per cent
Carbon	0.85 "
Silicon	0.20 "
Manganese	0.50 "
Magnesium	2.50 "
Vanadium	1.50 "
Molybdenum	5.00 "
Chromium	6.50 "

STANDARDIZATION

It does not appear that any standard form of testing method is in use for either heavy or light alloy die castings in Europe. In Great Britain, where specifications exist, they are based on the British Engineering Standards which cover a limited range of light alloys but have no specific reference to die castings. Test bars are poured in permanent molds and are considered to give a criterion of the properties of the alloy as well as being a check on the melting practice, but test bars are not considered to constitute any check on the final casting and no attempt has evidently been made to produce die cast coupons. The die casting industry is evidently quite competitive in Europe, and is apparently not cooperative to the extent where the various producers will agree on standardization or testing on a common basis.

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1922 F. A. Livermore, "Aluminum Die Casting," *Automobile Engineer*, Vol. 12, p. 341.
1923 "Die Casting Machine," *Engineering Production*, London.
1924 H. Chase, "Some Notes on Die Castings," *Mechanical World*, Vol. 75, p. 167.
1924 B. Wellman, "Die Spritzgussfertigung," *Werkstattstechnick*, Vol. 18, p. 620.
1924 "Die Spritzgussverfahren," *Zeitschrift für die Gesamte Giesserei Praxis*, Vol. 45, p. 114 (Serial).
1925 "Pressure Die Casting Machines," *Machinery* (London), Vol. 26, p. 280.
1925 H. P. Otto, "Die Verbilligung des Erzeungnisses und Die Spritzgussverfahren," *Maschinenbau*, Vol. 4, p. 11.
1925 F. Ehrmann, "Herstellung und Verwendung der Spritzguss," *Zeitschrift für Metallkunde*, Vol. 17, No. 10.
1925 A. H. Mundey, "Die Casting," *Metal Industry* (London), Vol. 26, p. 81.
1925 N. F. Budgen, "Die Castings," *The Engineer*, Vol. 120, p. 777.
1925 J. Marretsch, "Spritzgussverfahren in der Massenfertigung," *Werkstattstechnik*, Vol. 19, No. 10.

1925 L. Frommer, "Spritzguss," *Werkstattstechnik*, Vol. 20, Nos. 4–6.

1925 A. Kaufman, "Spritzgussverfahren und Maschinen," ***Zeitschrift***, der Verein Deutscher Ingenieure, Vol. 70, No. 9.

1925 L. Frommer, "Der Spritzguss und seine aufgabe für die Metallkunde," *Zeitschrift für Metallkunde*, Vol. 17, Nos. 8–9.

1926 George Mortimer, "Die Casting of Aluminum Alloys," ***Proceedings***, Inst. of Metals, Vol. 35, pp. 383–384.

1926 A. H. Mundey, "Die Castings," *Mechanical World*, Vol. 79, p. 189.

1926 E. J. Bedford, "Production of Pressure Die Castings," ***Machinery*** (London), Vol. 28, p. 33.

1926 G. A. Fritze, "Aluminum und Messing Spritzguss," ***Gewerbefleiss***, Vol. 105, p. 189.

1927 "Pressure Dies for Die Casting," *Machinery* (London), Vol. 30, p. 685.

1927 F. A. Livermore, "Notes on Aluminium Die Casting," ***Metal Industry*** (London), Vol. 30, p. 571.

REPORT OF COMMITTEE B-3

ON

CORROSION OF NON-FERROUS METALS AND ALLOYS

Since submitting its last report, Committee B-3 has been active through its various sub-committees as described below:

Sub-Committee I on Total Immersion Tests.—Sub-Committee I has held several meetings and has discussed revisions in procedure for carrying out a second series of total immersion and aerated tests. Actual work on this second series of tests had not been started.

Sub-Committee II on Alternate Immersion Tests.—There is no report to make at this time as the sub-committee has been inactive this past year due to the lack of a sufficient number of people who signified their intentions of carrying on further tests.

Sub-Committee III on Spray Tests.—This sub-committee has held three meetings during the past year for the purpose of arriving at definite recommendations concerning a standardized spray apparatus. Under date of March 17, 1927, Mr. R. M. Curts, of the New Jersey Zinc Co., submitted a tentative recommendation for a spray testing apparatus. In this report it was recommended that comparative performance tests be run on the various types of nozzles which were being used by the various members of the sub-committee. The work of testing out the spray nozzles was undertaken by Mr. Curts, and ten different nozzles were received and tested, the results being reported to the sub-committee under date of December 19. Mr. Curts concluded that all the spray nozzles submitted for test performed more or less satisfactorily, and probably each one has its particular merit. The great difference in the amount of liquid sprayed per hour by different nozzles at equal pressures and the difference in the amount of liquid sprayed per hour by the same nozzle under different pressures, as well as the variations in fineness of the spray, gave an indication of the varying conditions which must have existed in each laboratory during the testing program.

After carefully considering these reports, the sub-committee still felt that it was not yet in a position to make definite recommendations concerning a standardized spray equipment. It felt that further cooperative testing in the matter of spray nozzle design and construction would be desirable, but none of the members was able to undertake this amount of testing, at least for the present. It seemed to be the consensus of opinion that the interest of the majority of the members of Committee B-3 was focused on the testing program being undertaken by the newly formed sub-committees, and that until this program was well under way it would be undesirable to undertake any extensive work in Sub-Committee III.

Sub-Committee IV on Definitions.—This sub-committee has come to the conclusion that work on definitions of various terms relating to corrosion could best be done by a joint committee made up of members from the various standing committees of the Society who are dealing with problems of corrosion. This would avoid duplication of effort and standardize the meaning of such terms as are used in connection with corrosion problems on non-ferrous metals and alloys or on ferrous metals and alloys.

Sub-Committee V on Accelerated Electrolytic Tests.—Sub-Committee V has held one meeting during the past year. The original work of the sub-committee was completed and the sub-committee is being kept intact in case Sub-Committee VIII on Electrolytic and Galvanic Corrosion has some work for it to do.

The sub-committee is arranging to run some tests by the Blum-Rawdon method as described by W. Blum and H. S. Rawdon of the Bureau of Standards in a paper entitled "Principles of Electrolytic Studies on Corrosion" presented before the American Electrochemical Society in April, 1927. The tests are to determine whether the results of individual tests by this method will give check results and, if possible, what relation these results will have to the results of service tests.

Sub-Committee VI on Atmospheric Corrosion.—There has been little activity in this sub-committee as it has been awaiting funds in order to go ahead with the program substantially as outlined in the last annual report. A few minor changes have been made in the exposure samples, another aluminum alloy has been added to the list so that the total materials now included in the program number twenty-two.

At the request of Sub-Committee XV on Die-Cast Metals and Alloys of Committee B-2 on Non-Ferrous Metals and Alloys, arrangements are being made to extend the outdoor exposure racks of Committee B-3 to accommodate racks holding aluminum and zinc-base pressure die-cast specimens being studied by that committee. Committee B-3 is also endeavoring to obtain sufficient funds to finance the building of the special racks necessary for this work on die castings.

Sub-Committee VII on Corrosion in Liquids.—Sub-Committee VII has completed the necessary arrangements for carrying out twelve different field tests, against four types of solutions under conditions which are typical of those existing in some industrial process in general use. The sub-committee has also selected the metals which are to be included in each test and has specified the dimensions of all test specimens. The corrosive action of the solutions on each metal is to be reported in terms of weight lost, and also in terms of tensile strength.

The following program of tests will be started shortly:

1. *Sodium Chloride Solution.*—Two field tests are to be carried out in which a series of metal specimens will be immersed in sodium chloride solutions. In one the metals will be immersed in ordinary sea water used for cooling purposes in condensers. In the other, the metals will be immersed in the "mother liquor" in a grainer employed for the production of common salt.

Three specimens from each of the following metals will be included in each of the two field tests:

DESIGNATION	TYPICAL ANALYSES
A	Cu, 99.9 per cent
B	Cu, 99.9 per cent; P, 0.02 per cent
C	Cu, 94.5 per cent; Si, 4.5 per cent; Mn, 1 per cent
D	Cu, 92 per cent; Sn, 8 per cent
E	Cu, 95 per cent; Al, 5 per cent
F	Cu, 92 per cent; Al, 8 per cent
H	Cu, 89 per cent; Al, 10 per cent; Fe, 1 per cent
J	Cu, 88 per cent; Al, 7.5 per cent; Fe, 3.5 per cent; Ni, 1 per cent
K	Cu, 65 per cent; Zn, 23 per cent; Al, 6 per cent; Mn, 4 per cent; Fe, 2 per cent
L	Cu, 85 per cent; Zn, 15 per cent
M	Cu, 70 per cent; Zn, 30 per cent
N	Cu, 70 per cent; Zn, 29 per cent; Sn, 1 per cent
P	Cu, 75 per cent; Ni, 20 per cent; Zn, 5 per cent
Q	Cu, 70 per cent; Ni, 29 per cent; Sn, 1 per cent
R	Cu, 80 per cent; Ni, 20 per cent
S	Ni, 68 per cent; Cu, 28 per cent; others, 4 per cent
T	Ni, 99 per cent
V	Cr, 14 per cent; C, 0.10 per cent; Fe, balance
W	Cr, 18 per cent; Ni, 8 per cent; Fe, balance
Y	Cu, 75 per cent; Pb, 15 per cent; Sn, 10 per cent

2. *Sodium Hydroxide.*—Three field tests are to be carried out in vacuum evaporators in which a series of metal specimens will be immersed in caustic soda solutions.

In the first test, the metals will be immersed in weak caustic soda solution in a first stage evaporator in the commercial production of caustic soda. The second test will be in a last stage evaporator in the commercial production of caustic soda. The third test will be in "black liquor" as received by the evaporator recovering caustic soda from a paper making process.

Three specimens from each of the following metals will be included in each of the three field tests:

DESIGNATION	TYPICAL ANALYSES
A	Cu, 99.9 per cent
D	Cu, 92 per cent; Sn, 8 per cent;
H	Cu, 89 per cent; Al, 10 per cent; Fe, 1 per cent
J	Cu, 88 per cent; Al, 7.5 per cent; Fe, 3.5 per cent; Ni, 1 per cent
L	Cu, 85 per cent; Zn, 15 per cent
M	Cu, 70 per cent; Zn, 30 per cent
N	Cu, 70 per cent; Zn, 29 per cent; Sn, 1 per cent
P	Cu, 75 per cent; Ni, 20 per cent; Zn, 5 per cent
Q	Cu, 70 per cent; Ni, 29 per cent; Sn, 1 per cent
R	Cu, 80 per cent; Ni, 20 per cent
S	Ni, 68 per cent; Cu, 28 per cent; others, 4 per cent
T	Ni, 99 per cent
W	Cr, 18 per cent; Ni, 8 per cent; Fe, balance

3. *Hydrochloric Acid.*—Three field tests are to be carried out in which a series of metal specimens will be immersed in hydrochloric acid solution. In each, the metals will be immersed in a pickling solution typical of those used for pickling steel parts, prior to such operations as enameling.

Three specimens from each of the following metals will be included in each of the three field tests:

DESIGNATION	TYPICAL ANALYSES
C	Cu, 94.5 per cent; Si, 4.5 per cent; Mn, 1 per cent
D	Cu, 92 per cent; Sn, 8 per cent
H	Cu, 89 per cent; Al, 10 per cent; Fe, 1 per cent
J	Cu, 88 per cent; Al, 7.5 per cent; Fe, 3.5 per cent; Ni, 1 per cent
K	Cu, 65 per cent; Zn, 23 per cent; Al, 6 per cent; Mn, 4 per cent; Fe, 2 per cent
S	Ni, 68 per cent; Cu, 28 per cent; others, 4 per cent
T	Ni, 99 per cent
X	Si, 14.5 per cent; Mn, 0.3 per cent; Cu, 0.4 per cent; Fe, balance

4. *Sulfuric Acid.*—Four field tests will be carried out in which a series of metal specimens will be immersed in sulfuric acid solution.

Two will be in solutions as used for pickling steel prior to galvanizing.

In the third test, the metals will be immersed in a pickling solution as used for pickling steel prior to tin plating.

The fourth will be in a solution typical of that used for pickling automobile body sheets, prior to cold rolling.

Three specimens from each of the following metals will be included in each of the four field tests:

DESIGNATION	TYPICAL ANALYSES
A	Cu, 99.9 per cent
C	Cu, 94.5 per cent; Si, 4.5 per cent; Mn, 1 per cent
D	Cu, 92 per cent; Sn, 8 per cent
H	Cu, 89 per cent; Al, 10 per cent; Fe, 1 per cent
J	Cu, 88 per cent; Al, 7.5 per cent; Fe, 3.5 per cent; Ni, 1 per cent
K	Cu, 65 per cent; Zn, 23 per cent; Al, 6 per cent; Mn, 4 per cent; Fe, 2 per cent
L	Cu, 85 per cent; Zn, 15 per cent
M	Cu, 70 per cent; Zn, 30 per cent
N	Cu, 70 per cent; Zn, 29 per cent; Sn, 1 per cent
P	Cu, 75 per cent; Ni, 20 per cent; Zn, 5 per cent
Q	Cu, 70 per cent; Ni, 29 per cent; Sn, 1 per cent
R	Cu, 80 per cent; Ni, 20 per cent
S	Ni, 68 per cent; Cu, 28 per cent; others, 4 per cent
T	Ni, 99 per cent
U	Pb, 99.9 per cent
Y	Cu, 75 per cent; Pb, 15 per cent; Sn, 10 per cent

Instead of making three simultaneous tests of different duration, as originally planned, it was decided to make the first test a short one, to obtain easily determinable weight losses, and then follow with tests of double and triple this time, to get the necessary three points on a time curve.

Due to the difficulty of making arrangements with the plants in which tests will be made, it was found necessary to delay the inclusion of such pieces of practical equipment, as pickle pins, evaporator tubes, etc., in the field tests, until the first set of results are obtained and it is more definitely established by Sub-Committee VIII just what galvanic effect is likely to take place in the apparatus. Sub-Committees VII and VIII are cooperating in their work to establish such points.

Sub-Committee VIII on Galvanic and Electrolytic Corrosion.—Sub-Committee VIII on Galvanic and Electrolytic Corrosion has formulated the following program for studying the corrosion which may occur at points of contact between dissimilar metals:

1. When exposed to outdoor and indoor atmospheric conditions.
2. When immersed in electrolytes of high, medium and low conductivity and in hot water.

Galvanic Corrosion in Outdoor and Indoor Exposure: According to present plans all of the field test locations of Sub-Committee VI will be used in making galvanic corrosion tests. Twenty-three couples as listed below will be tested:

Aluminum with aluminum, copper, iron, tin and zinc.
Copper with copper, iron, lead, tin and zinc.
Iron with iron, nickel, lead, tin and zinc.
Lead with lead, nickel and zinc.
Nickel with nickel, tin and zinc.
Tin with tin, zinc with zinc.

A design of couple has been decided upon, consisting of punched disks of metals, 1½ in. in diameter and ⅛ in. thick, bolted together at the center. The couple will be separately mounted and suitably insulated from the clamping bolt and supporting frame by means of bakelite bushings and washers. A preliminary set of couples will be immediately put out at the New York location to determine the proper technique of handling the installation of the regular tests and examination of the specimens after exposure.

Electrolytic Complete Immersion Tests: Complete Immersion Tests will be carried out in conjunction with Sub-Committee VII. The field test locations arranged by that committee will be available to Sub-Committee VIII for the installation of its test racks. Standard tension test specimens[1] of typical metals and alloys, picked from the list of Sub-Committee VII, coupled as indicated below, will be tested in the following locations:

1. In one sulfuric acid pickling tank; all couple combinations oft he following metals:

Electrolytic copper
Soft lead
Brass (70–30)
Tin Bronze
Monel Metal
Copper Nickel Alloy (80–20)
Allegheny Metal

2. In one sodium hydroxide concentrator; all couple combinations of the following metals:

Electrolytic Copper
Brass (70–30)
Monel Metal
Copper Nickel Alloy (80–20)

3. In one sea water location; all couple combinations of the following metals:

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[1] See Tentative Methods of Tension Testing of Metallic Materials (E 8 – 27 T), *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 1067 (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 725.

Electrolytic Copper
Soft Lead
Brass (70–30)
Tin Bronze (92 per cent copper, 8 per cent tin)
Monel Metal
Copper Nickel Alloy (80–20)
Allegheny Metal (18 per cent chromium, 8 per cent nickel, balance iron)

4. In hot water; all of the couples listed under sea water.

All of the couples to be tested in the galvanic outdoor exposure will also be included in the sea water and hot water tests. According to the present plan the couples will be separately mounted in a vertical position with a metallic connection between the two elements of each couple at the lower end, which will be embedded in an asphaltic mixture or other insulation composition able to withstand the temperature and liquid to which it is subjected.

Financing of Investigations:

The tests and investigations outlined above are the most comprehensive of any corrosion tests on non-ferrous metals ever undertaken by a technical society. In order to provide the necessary funds for these investigations the committee is endeavoring to raise by subscription the sum of $6500. Letters have been addressed to organizations who should be interested in this work and who would profit as the result of the tests being made. This solicitation is not confined to committee members but includes a number of firms not represented on the committee, including both producers and non-producers. Up to the present time, $4250 have been contributed.

The committee has re-elected the present officers to serve for the ensuing term of two years.

This report has been submitted to letter ballot of the committee, which consists of 38 members; 30 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

T. S. FULLER,
Chairman.

SAM TOUR,
Secretary.

REPORT OF COMMITTEE B-4

ON

METALLIC MATERIALS FOR ELECTRICAL HEATING

Two meetings of the committee have been held during the year, as follows, in addition to the one to be held during the annual meeting of the Society: On October 7 and 8, 1927, at Washington, D. C., and on March 12 and 13, 1928, at Philadelphia, Pa.

Two members have been added to the committee during the year and one has resigned, leaving the membership 16, classified as 8 non-producers, 6 producers and 2 general interests.

Tentative Methods of Chemical Analysis (B 71 - 27 T).[1]—A proposed method of chemical analysis for sulfur by the evolution-titration method is appended[2] to this report and is recommended to be added to these methods. A sample of nickel-chromium wire analyzed by three laboratories by this method showed agreement in results as follows:

	Sulfur, per cent	
Laboratory	Nickel-Chromium Alloy	Iron-Nickel-Chromium Alloy
No. 1	0.033	0.018
No. 2	0.032	0.019
No. 3	0.030	0.018

The method was submitted to Mr. G. E. F. Lundell, chairman of the Technical Committee on Chemical Composition of Committee E-1 on Methods of Testing, and several changes suggested by him have been included. Methods of chemical analysis for copper are being investigated.

Life Test.—The test for the durability of electrical heating wires at high temperatures has been actively followed during the year. The method under consideration provides an intermittent test in which the vertical specimen has a current cycle of two minutes on and two minutes off, under constant voltage conditions. Temperature is measured by means of a modified form of optical pyrometer. The intermittent test gives a much shorter life than the continuous test at the same temperature and corresponds to intermittent service of various household electrical heating appliances. Changes in details of the method have been made in order to obtain more uniform conditions and better checks in tests made by different laboratories, and additional tests are being made. It has been found necessary to closely control the voltage and initial temperature, and also to shield the specimens from drafts of air. Efforts are also being made to improve the lamp in the optical pyrometer. In addition to the life of the specimen, the method includes determination of the increase in electrical resistance, throughout its life.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, **Part I, p.** 761 (1927); also 1927 Book of A.S.T.M. Standards, p. 176.

[2] See p. 799.—Ed.

Temper.—A method of testing uniformity of temper of wire by determining the uniformity of stretch of a helical coil made from the wire has been outlined and is being investigated.

Growth.—Three test runs were completed on samples of 80–20 nickel-chromium wire to determine whether or not the apparent growth was due to externally applied stresses. Two samples were heated externally in a muffle furnace at 1000° C. for about eleven hours each day and one sample was heated by the passage of current. These tests extended over a period of 16 days and additional tests were made to eliminate the possibility that some unlooked-for factors might develop. The results thus far indicate that the so-called "growth" is in reality plastic deformation under externally applied stress.

In view of the importance of plastic flow phenomena, the activities of the committee have been extended to include the development of tests to determine the mechanical stability of electrical heating materials under service conditions.

The following tentative methods of test are recommended to be continued as tentative in their present form:

Method of Test for Resistivity of Metallic Materials for Electrical Heating (B 63 – 26 T);
Method of Test for Change of Resistance with Temperature of Metallic Materials for Electrical Heating (B 70 – 27 T).

When the committee was organized the members requested that the scope of the work be limited to electrical heating wires, thus excluding resistance wires which would require a somewhat different personnel on the committee. The work has progressed to the stage where it is now considered advisable to extend the activities of the committee to include resistance wires and enlarge the membership. The committee has requested the Executive Committee to authorize this step.

The following is the result of the letter ballot vote of the committee, which consists of 16 members, on the proposed addition to the Tentative Methods of Chemical Analysis of Metallic Materials for Electrical Heating (B 71 - 27 T): Affirmative, 11; negative, 0; not voting, 5.

The committee has re-elected the present officers to serve for the ensuing term of two years.

This report has been submitted to letter ballot of the committee, which consists of 16 members; 11 members returned their ballots, of whom 10 have voted affirmatively, none negatively, and 1 has marked his ballot "not voting."

Respectfully submitted on behalf of the committee,

DEAN HARVEY,
Chairman.

F. E. BASH,
Secretary.

EDITORIAL NOTE

The proposed revisions of the Tentative Methods of Chemical Analysis of Metallic Materials for Electrical Heating were accepted. The tentative methods in their revised form appear on page 799.

REPORT OF COMMITTEE C-1

ON

CEMENT

During the past year, Committee C-1 has held two very well-attended meetings. At both of these the sub-committee reports appended hereto were a matter of detailed discussion. The investigation which these reports cover has been in progress for a period of about two years. A very brief outline of the entire series of tests can be found in the introductory paragraphs of the report of Sub-Committee VII on Strength. The magnitude of the work can possibly be realized when it is stated that there were made and tested over 63,000 strength specimens alone. The very brief summaries of the data secured and presented in the several reports will also assist in enabling one to visualize the extent of the study.

The investigation was originally planned by Sub-Committee VII on Strength. The data, however, where they pertained to the work of other sub-committees were referred to these for further study. As a result, several of the sub-committees have had data available which enable them to realize what character of results a large group of laboratories will secure when testing a large number of cements, made in practically all parts of the country, with the methods prescribed by these sub-committees.

Some of these data are disappointing both in respect to the wide variation in results obtained by the different laboratories and in respect to the lack of positive trends indicated. Thus, the results of the fineness tests, the determination of the normal consistency, and the time of set determination all show a lamentable lack of concordance. These are especially cited as they are simple tests, requiring little manipulation or refined apparatus. The report of the Sub-Committee on Fineness, where it refers to why there has been unsatisfactory agreement, should be studied particularly. It will be noted that when properly calibrated equipment is used as defined by the committee good agreement will result. But it is surprising to note that such a large number of laboratories will not take the pains to do even simple things properly, with proper apparatus.

The report of the Sub-Committee on Chemical Limitations is somewhat like that of the Sub-Committee on Strength, in that its conclusions lack positiveness. However, this apparent lack of conclusive relation between chemical composition or calculated constitution and strength may be due solely to attempting to make this study with cement secured from warehouses. In such a case as this there is introduced the additional variables of character and amount of grinding of the clinker, character and amount of retarder used, and character and amount of change due to storage. In studies to determine these relations, it would be more desirable to avoid these variables by grinding various clinkers in one mill, using the same amount of the same retarder, and making the specimens immediately after finishing the cements. The fluid mixes proposed by the Sub-Committee on Strength are disappointing. The data show that an inexperienced operator cannot secure the concordant results that were expected, and furthermore the results are not any more indicative of the strength of the cement in question in a concrete than are those obtained from carrying out the tests according to the present requirements of the Society.

The committee wishes especially to call attention to the fact that the conclusions presented in the sub-committee reports are given particularly for the purpose of indicating the reaction of the committee in studying and analyzing the data. Others may see much of interest in the data and may draw other or different conclusions. If such is the case the committee should indeed be pleased to have these. They may be of especial value in assisting in planning the future work.

Those who are inclined to believe that the requirements of the present A.S.T.M. Standard Specifications for Portland Cement (C 9 – 26) are low should study with care Table XI of the report of Sub-Committee VII on Strength. When different reputable laboratories do secure results as widely variant as these indicated, and when some of these would have condemned a cement as not meeting the requirements when so many other laboratories would have approved the cement as meeting those same requirements, it is plainly evident that for a national standard, for a country geographically as large as ours, tolerances must be considerably greater than any one individual consumer might wish to employ. All of these cements would have been passed by the majority of the laboratories, yet three of the laboratories (and quite reputable laboratories, in widely separated parts of the country) would have rejected practically all of the cements. That these laboratories felt that their results were satisfactory is indicated by their handing them on to the committee. But with such evidence before it, some of the members of the committee can hardly help feeling that it might have been even more tolerant in setting its requirements.

During the present meeting of the Society the committee will discuss the type of work which it will undertake during the coming year. The inadequacy of the present tension briquet made of any cement for indicating what will be the strength of a concrete made from the same cement shows that the committee must study other methods of test. The briquets or small compression test pieces of fluid neat pastes have also been shown to be lacking in this respect. Hence the committee will look to the development of entirely new methods. Mr. E. M. Brickett has designed a graded sand mortar which in the laboratory of the Lehigh Portland Cement Co. has given most promising results,[1] and the committee will carefully study his results in laying out a new program. It would seem also desirable to study any proposed methods rather intensively in a small number of laboratories which have shown their ability to reproduce results within a reasonable degree of concordance before asking the cooperation of a large number of laboratories. The aid of the larger number should be sought when the committee feels that it needs an indication of the tolerances which must be adopted with the requirements to take care of the reasonable inability of widely scattered laboratories to accurately reproduce each other's results.

At the annual meeting, the Advisory Committee will give serious thought to a resolution submitted to it by the committee as a result of a study of the appended data. These, as well as other previously obtained data, indicate that the various laboratories do not obtain the concordance in their testing that good commercial practice demands. Whether a cement is meeting the requirements of the standards seems now too frequently to be a matter of choice of laboratory. Hence the Advisory Committee has been instructed to appoint a committee to study this situation along the lines of establishing a special laboratory where instructions could be given in carrying out the tests according to the prescribed methods, where the equipment used in testing could be calibrated and examined to see if it met with the desired requirements and which could, when so requested, act as an umpire in settling disputes between laboratories as to any test requirement. This is a matter of considerable moment, as it is an attempt to develop an active central medium which would be recognized as authoritative in the interpretation and application of testing methods to cement. This concerns not only this committee and the Society but all other organizations interested in cement testing, and possibly the testing of other materials. The development or failure of development of the idea should be of much concern to this organization.

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[1] See paper by E. M. Brickett on "A Plastic Mortar Compression Test for Cement," *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part II, p. 432 (1928).

During the year a Sub-Committee on Apparatus was organized. The creation of this sub-committee resulted from the lack of definiteness of the requirements for equipment given in our present standard specifications. In fact it rather developed from the placing of certain requirements for some few pieces of apparatus in the present revised standard and omitting the requirements for the remainder of the apparatus. The attempt at making the characteristics of the equipment more definite emphasized the general lack of definiteness of description and dimensions with so much of the equipment. The subcommittee has indeed much work ahead of it before our specifications have the definiteness that is positively needed. However, that is a particular reason for especial activity on its part.

Again the committee must beg the indulgence of the Society in regard to its lack of change of attitude towards the oldest standard and tentative standard for which it is responsible, the Standard Specifications for Natural Cement (C 10 – 09) and the Tentative Specifications and Tests for Compressive Strength of Portland Cement Mortars (C 9 – 16 T). In the former case, while the committee has not accomplished a much needed revision, it is rather to be congratulated upon its "innocuous desuetude." This is due to the fact that at the present time there is very marked revival of interest in cements other than standard portland, by both manufacturers and users where a very plastic or workable mortar is demanded. This use may be met by natural cements, or by modifications of them, or by modifications of portland cement. Since the production of them is still not based upon a well-defined measurable property of quality, indicating their ability to meet the demands of their particular use, it would seem advisable for the committee to mark time until the production and use had shown more clearly what are the essential properties of these cements.

In respect to the mortar compression test specimens, it may be said that none of the work of the committee since the submission of the tentative standard has indicated with the desired conclusiveness the essential requirements for a mortar compression specimen. The data have shown that, all things considered, the 2-in. cube would be preferable to the 2 by 4-in. cylinder of the tentative standard. But the data have not shown conclusively what should be the characteristics of the sand used, what the proportions of sand and cement, and how much water should be used. If the strength developed by the cement in a mortar is to be indicative of the strength developed by the same cement in a concrete, then the committee has considerable ahead of it in studying both mortars and concretes. It is, therefore, recommended that Tentative Specifications C 9 - 16 T be continued as tentative.

The committee has re-elected the present officers to serve for the ensuing term of two years.

This report has been submitted to letter ballot of the committee which consists of 72 members; 70 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

P. H. BATES,
Chairman.

F. H. JACKSON.
Secretary.

REPORT OF SUB-COMMITTEE I ON DEFINITIONS AND CHEMICAL LIMITATIONS

Sub-Committee I on Definitions and Chemical Limitations submits this report on the results of the chemical analyses of the 32 cements used in the cooperative investigation sponsored by Sub-Committee VII. The sub-committee has made studies of these data and this report is an attempt to correlate the results of the chemical analyses with the results of the physical tests.

DISCUSSION OF CHEMICAL COMPOSITION

The chemical analyses of the 32 portland cements as reported by the five laboratories which made complete analyses of the various cements are given in Table I. The results of the five laboratories check within very close limits, and, therefore, the average value of the different constituents for each cement can be considered as the true value.

All cements complied with the A.S.T.M. Specifications C 9–26 as to chemical limitations, except cements 4 and 25. All five laboratories show cement 4 to be above the limit for MgO. Two of the five laboratories found the SO_3 too high in cement 25.

Table II shows the average results of the chemical analysis taken from Table I, the potential constitution (calculations made by a method shown in Mill Section of *Concrete*, August, 1927), total silicates, the lime-silica index (a specification for portland cement presented to Committee C-1, March 27, 1926) and certain ratios of various constituents which have at times been proposed for inclusion in cement specifications. For convenience in studying the relationships which may be involved the average results of the various physical tests have been included in this table.

The curves in Fig. 1 were drawn arranging the cements in order of descending compressive strength of concrete at 28 days. In no case could there be found any curve representing the chemical values, ratios or calculated compounds that could be said to be an indication of the concrete-making value of the cement. However, the curves plotted showed the following general trends based on 28-day strength of concrete:

1. Ratio of SiO_2 to R_2O_3 increased as the strength decreased,
2. The lime-silica index decreased as the strength decreased,
3. Ratio of CaO to $SiO_2 + R_2O_3$ decreased as strength decreased,

4. The $3CaO \cdot SiO_2$ decreased as strength decreased,
5. The $2CaO \cdot SiO_2$ increased as the strength decreased,
6. The $3CaO \cdot Al_2O_3$ decreased as strength decreased.

The lime-silica index, the ratio CaO to $SiO_2 + R_2O_3$ and the $3CaO \cdot SiO_2$ curves seem to parallel each other throughout the series.

From the curves shown on Fig. 1 the following approximate equivalents can be calculated:

$3CaO \cdot SiO_2$	Lime-Silica Index	$\frac{CaO}{(SiO_2 + R_2O_3)}$
45.0	2.32	2.10
37.5	2.25	2.05
30.0	2.18	2.00

It should be remembered that the calculations of potential constitution are based on assumptions as to the composition of the compounds present in portland cement which may not be entirely justified. As knowledge of the complex reactions of cement manufacture and use increases, such calculations will doubtless assume greater importance. Inclusion in Standard Specifications C 9 of requirements based on potential constitution seems a matter of future development rather than an immediate possibility.

Respectfully submitted on behalf of the sub-committee,

G. A. SAEGER,
Chairman.

TABLE I.—CHEMICAL ANALYSES OF CEMENTS, PER CENT BY WEIGHT.

Laboratory	Cements 1-32																																Average Value	High Value	Low Value
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32			
SILICA (SiO_2)																																			
No. 10....	21.20	21.30	22.10	21.60	20.80	20.70	21.70	23.10	21.80	22.80	21.50	22.30	21.40	22.0	21.20	21.70	20.80	22.30	22.50	22.70	20.20	21.30	22.20	21.60	21.90	22.80	21.0	21.50	21.0	21.0	22.20	23.20	21.73	23.20	20.20
No. 16....	21.19	22.69	22.35	21.05	20.22	20.26	21.30	22.59	21.36	22.23	21.32	22.28	21.14	21.98	20.78	21.53	20.73	22.27	22.03	23.22	20.18	21.13	21.97	21.41	22.12	23.52	20.49	23.52	20.17	21.25	22.15	23.03	21.66	23.52	20.17
No. 19....	21.30	23.23	22.94	21.43	20.84	20.96	21.87	23.37	22.03	22.76	21.52	22.28	21.45	22.55	21.40	22.03	21.47	22.83	22.34	23.70	20.90	21.42	22.53	22.01	22.57	23.90	21.12	23.80	20.62	21.65	22.40	23.44	22.14	23.90	20.62
No. 35....	21.49	22.94	22.64	20.94	20.66	20.38	21.58	22.86	21.43	22.37	21.42	22.51	21.42	22.30	20.88	21.74	20.98	22.64	22.14	23.46	20.35	22.14	22.23	21.64	22.19	23.81	20.64	23.67	20.42	21.56	22.31	23.28	21.88	23.81	20.35
No. 37....	21.80	22.30	23.26	21.44	20.90	20.50	21.70	23.24	21.82	22.50	21.64	22.56	21.30	22.46	21.24	22.04	21.28	22.54	22.42	23.54	20.40	21.22	22.46	22.10	22.64	24.16	21.06	23.80	20.44	21.68	22.66	23.66	22.10	24.16	20.40
Aver. value	21.40	22.49	22.66	21.29	20.68	20.56	21.63	23.03	21.69	22.53	21.48	22.39	21.34	22.26	21.10	21.81	21.05	22.52	22.29	23.32	20.41	21.44	22.28	21.75	22.28	23.64	20.86	23.26	20.53	21.43	22.34	23.32	21.92	23.72	20.35
High value	21.80	23.23	23.26	21.60	20.90	20.96	21.87	23.37	22.03	22.80	21.64	22.56	21.45	22.55	21.40	22.04	21.47	22.83	22.50	23.70	20.90	22.14	22.53	22.10	22.64	24.16	21.12	23.80	21.0	21.68	22.66	23.66	22.26	**23.64**	**20.41**
Low value.	21.19	21.30	22.10	20.94	20.22	20.26	21.30	22.59	21.36	22.23	21.32	22.28	21.14	21.98	20.78	21.53	20.73	22.27	22.03	22.70	20.18	21.13	21.97	21.41	21.90	22.80	20.64	21.50	20.17	21.0	22.15	23.03	21.50	.....	.....
IRON OXIDE (Fe_2O_3)																																			
No. 10....	2.80	4.60	3.00	2.50	3.10	3.60	2.60	3.20	2.30	2.00	3.00	4.60	3.00	2.20	2.40	3.20	4.40	2.60	2.30	1.70	2.60	2.60	3.20	2.70	2.00	1.80	3.00	3.60	3.60	2.50	3.50	3.80	2.94	4.60	1.70
No. 16....	3.01	4.43	2.90	2.53	3.10	3.47	2.34	3.12	2.07	2.34	2.99	4.73	3.03	2.34	2.67	3.03	4.09	2.73	2.30	1.88	2.71	2.62	3.35	2.62	2.16	1.95	2.76	3.72	3.56	2.41	3.49	3.72	2.93	4.73	1.88
No. 19....	3.12	4.48	2.64	2.88	3.12	3.52	2.56	3.08	2.23	2.24	2.96	4.56	3.36	2.32	2.64	3.28	4.00	2.80	2.16	1.76	2.48	2.40	3.04	2.64	1.84	1.68	2.80	3.60	3.44	2.56	3.36	3.76	2.92	4.56	1.68
No. 35....	2.97	4.37	2.77	2.80	2.96	3.30	2.50	3.00	1.96	2.20	2.72	4.25	2.84	2.18	2.38	2.78	3.78	2.54	2.10	1.87	2.47	2.90	3.05	2.51	1.92	1.78	2.54	3.58	3.36	2.28	3.22	3.51	2.79	4.37	1.78
No. 37....	3.05	4.30	2.88	2.80	2.95	3.25	2.55	3.05	2.15	2.45	2.85	4.65	3.20	2.35	2.50	3.00	4.45	2.50	2.20	2.25	2.65	2.25	3.55	2.90	2.95	1.95	3.10	3.65	3.65	2.30	3.40	3.60	2.98	4.65	1.95
Aver. value	2.99	4.44	2.84	2.70	3.04	3.43	2.51	3.09	2.14	2.25	2.90	4.56	3.09	2.28	2.52	3.06	4.14	2.63	2.21	1.89	2.58	2.55	3.24	2.67	2.17	1.83	2.84	3.63	3.52	2.41	3.39	3.68	2.91	4.58	1.80
High value	3.12	4.60	3.00	2.88	3.12	3.60	2.60	3.20	2.30	2.45	3.00	4.73	3.36	2.35	2.67	3.28	4.45	2.80	2.30	2.25	2.71	2.90	3.55	2.90	2.95	1.95	3.10	3.72	3.65	2.56	3.50	3.80	3.06	**4.44**	**1.83**
Low value.	2.80	4.30	2.64	2.50	2.95	3.25	2.34	3.00	2.07	2.00	2.72	4.25	3.00	2.18	2.38	2.78	3.78	2.50	2.10	1.70	2.47	2.25	3.04	2.51	1.84	1.68	2.54	3.58	3.36	2.28	3.22	3.51	2.77	.....	.....
ALUMINUM OXIDE (Al_2O_3)																																			
No. 10....	6.60	3.90	6.00	5.80	6.70	5.70	7.10	6.50	6.20	6.50	6.00	4.40	7.70	6.60	7.00	6.50	5.20	6.00	6.40	4.60	7.40	6.70	6.50	6.40	7.50	5.30	7.20	5.80	4.30	6.50	4.60	4.90	6.06	7.70	3.90
No. 16....	6.70	3.51	6.54	5.92	6.05	5.49	7.13	5.76	5.92	6.11	5.65	3.95	7.33	5.93	6.73	6.39	6.31	5.57	5.76	4.07	6.92	6.25	5.19	5.63	5.89	4.71	7.55	5.28	5.57	6.41	4.28	5.01	5.80	7.55	3.51
No. 19....	7.28	3.79	6.86	5.84	6.14	5.21	7.22	6.07	5.70	6.39	5.65	4.29	6.99	5.80	6.66	5.97	6.46	5.32	5.90	4.26	6.93	6.53	5.72	5.92	6.65	4.74	7.32	5.43	5.56	6.44	4.64	4.98	5.89	7.32	3.79
No. 35....	6.91	3.29	6.79	5.70	6.14	5.70	7.02	6.07	6.26	6.49	6.19	4.42	7.52	6.09	7.22	6.88	6.93	5.70	6.17	4.17	7.44	6.09	5.56	5.91	6.48	4.77	7.96	5.56	6.04	6.76	4.64	5.28	6.08	7.96	3.29
No. 37....	6.79	3.70	6.42	5.86	6.15	5.75	6.91	5.69	6.09	5.63	5.55	3.73	6.90	5.61	6.78	6.38	6.05	5.60	6.20	4.15	6.95	6.65	4.95	5.78	5.15	4.59	7.20	5.15	5.39	6.50	4.54	5.16	5.74	7.20	3.70
Aver. value	6.86	3.63	6.52	5.83	6.24	5.57	7.08	6.02	6.04	6.22	5.81	4.16	7.28	6.00	6.88	6.44	6.19	5.64	6.09	4.25	7.13	6.45	5.58	5.93	6.34	4.82	7.45	5.64	5.41	6.52	4.54	5.06	5.91	7.55	3.64
High value	7.28	3.79	6.86	5.92	6.70	5.75	7.22	6.50	6.26	6.50	6.19	4.42	7.70	6.60	7.22	6.88	6.93	6.00	6.40	4.60	7.44	6.70	6.50	6.40	7.50	5.30	7.96	5.80	6.04	6.76	4.64	5.28	6.14	**7.45**	**3.63**
Low value.	6.60	3.29	6.00	5.70	6.05	5.21	6.91	5.69	5.70	5.63	5.55	3.73	6.90	5.61	6.66	5.97	5.20	5.32	5.76	4.07	6.92	6.09	4.95	5.63	5.15	4.59	7.20	5.15	4.30	6.41	4.28	4.90	5.61	.....	.....
IRON AND ALUMINUM OXIDES (R_2O_3)																																			
No. 10....	9.40	8.50	9.0	8.30	9.80	9.30	9.70	9.70	8.50	8.50	9.0	9.0	10.70	8.80	9.40	9.80	9.60	8.60	8.70	6.30	10.0	9.30	9.70	9.10	9.50	7.10	10.20	9.40	8.10	9.0	8.10	8.70	9.0	10.70	6.30
No. 16....	9.71	7.94	9.44	8.45	9.15	8.96	9.47	8.88	7.99	8.45	8.64	8.68	10.36	8.27	9.40	9.42	10.40	8.30	8.06	5.95	9.63	8.87	8.54	8.25	8.05	6.66	10.31	9.00	9.13	8.82	7.77	8.73	8.74	10.40	5.95
No. 19....	10.40	8.27	9.50	8.72	9.26	8.73	9.78	9.15	7.93	8.63	8.61	8.85	10.35	8.12	9.30	9.25	10.46	8.12	8.06	6.02	9.41	8.93	8.76	8.56	8.49	6.42	10.12	9.03	9.00	9.00	8.00	8.74	8.81	10.46	6.02
No. 35....	9.88	7.66	9.56	8.50	9.10	9.00	9.52	9.07	8.22	8.69	8.91	8.67	10.36	8.27	9.60	9.66	10.71	8.24	8.27	6.04	9.91	8.99	8.61	8.42	8.40	6.55	10.50	9.14	9.40	9.04	7.86	8.79	8.86	10.71	6.04
No. 37....	9.84	8.00	9.30	8.66	9.10	9.00	9.46	8.74	8.24	8.08	8.40	8.38	10.10	7.96	9.28	9.38	10.50	8.10	8.40	6.40	9.60	8.90	8.50	8.68	8.10	6.54	10.30	8.80	9.04	8.80	7.94	8.76	8.73	10.50	6.40
Aver. value	9.85	8.07	9.36	8.53	9.28	9.00	9.59	9.11	8.18	8.47	8.71	8.72	10.37	8.28	9.40	9.50	10.33	8.27	8.30	6.14	9.71	9.00	8.82	8.60	8.51	6.65	10.29	9.07	8.93	8.93	7.93	8.74	8.82	10.55	6.14
High value	10.40	8.50	9.56	8.72	9.8	9.3	9.78	9.7	8.5	8.69	9.0	9.0	10.70	8.8	9.60	9.8	10.71	8.6	8.7	6.40	10.0	9.3	9.7	9.1	9.5	7.1	10.50	9.4	9.40	9.04	8.1	8.79	8.89	**10.37**	**6.14**
Low value.	9.40	7.66	9.0	8.3	9.10	8.73	9.46	8.74	7.93	8.08	8.40	8.38	10.10	7.96	9.28	9.25	9.6	8.10	8.06	5.95	9.41	8.87	8.50	8.25	8.05	6.42	10.12	8.80	8.1	8.80	7.77	8.7	8.54	.....	.....

CALCIUM OXIDE (CaO)

No. 10....	63.70	65.0	62.0	61.0	62.0	63.50	61.60	62.70	62.0	61.50	62.50	63.30	62.50	63.70	62.80	63.0	63.70	62.50	61.30	61.70	63.50	64.0	62.30	63.80	63.0	64.30	62.60	63.50	64.10	61.70	63.30	64.20	62.90	65.0	61.00
No. 16....	64.67	65.03	61.78	60.25	61.42	64.03	61.68	63.51	61.60	61.43	61.87	63.25	63.53	63.78	62.77	62.43	63.49	62.32	62.42	60.90	62.74	64.54	62.80	64.00	62.71	63.82	61.39	62.06	63.96	61.55	62.18	63.49	60.78	65.03	60.25
No. 19....	64.73	64.96	64.12	60.51	61.87	64.24	62.01	63.75	62.08	61.51	62.86	64.12	63.50	64.53	63.15	62.90	63.51	62.83	62.97	61.45	63.57	65.50	63.15	64.57	63.12	63.92	61.93	62.10	64.35	61.90	62.80	63.72	63.20	65.50	60.51
No. 35....	64.66	64.58	61.83	60.23	61.43	64.00	61.64	63.68	62.04	61.69	62.47	64.06	63.58	64.08	62.74	62.61	63.44	62.51	62.44	61.11	62.85	63.13	62.82	64.18	62.93	64.00	61.32	62.13	64.28	61.91	62.71	63.69	62.84	64.66	60.23
No. 37....	64.84	65.56	61.90	60.24	61.64	64.44	61.80	62.80	62.14	61.98	62.90	63.56	62.64	63.78	63.00	62.98	63.98	63.06	62.70	61.10	63.20	63.66	63.46	64.04	62.70	62.74	62.16	62.40	64.20	61.48	62.90	64.24	62.95	65.56	60.24
Aver. value	64.52	65.03	62.33	60.45	61.67	64.04	61.75	63.29	61.97	61.63	62.52	63.66	63.15	63.97	62.89	62.79	63.62	62.64	62.37	61.25	63.17	64.17	62.91	64.12	62.89	63.76	61.88	62.44	64.18	61.71	62.78	63.87	62.92	65.17	60.45
High value	64.84	65.56	64.12	61.0	62.0	64.44	62.01	63.75	62.14	61.98	62.90	64.12	63.58	64.53	63.15	63.0	63.98	63.06	62.97	61.70	63.57	65.50	63.46	64.57	63.12	64.30	62.60	63.50	64.35	61.91	63.30	64.24	63.41	**65.03**	**60.45**
Low value.	63.70	64.58	61.78	60.23	61.42	63.50	61.60	62.70	61.60	61.43	61.87	63.25	62.50	63.70	62.74	62.43	63.44	62.32	61.30	61.10	62.74	63.13	62.30	63.80	62.70	62.74	61.32	62.06	63.96	61.48	62.18	63.49	62.44	.....	.....

MAGNESIUM OXIDE (MgO)

No. 10....	0.90	0.80	1.80	5.50	4.0	3.10	2.60	1.0	4.40	3.60	3.10	2.10	1.80	2.20	2.50	2.10	1.30	2.90	2.80	3.70	2.40	2.20	2.10	2.10	2.50	2.40	2.80	1.50	1.80	3.50	3.20	1.20	2.50	4.40	0.80
No. 16....	0.79	0.66	2.01	5.67	4.72	3.19	2.74	0.95	4.91	4.01	3.03	1.80	1.21	2.22	2.77	2.03	1.20	3.13	3.14	4.34	2.44	1.30	2.05	1.84	2.51	2.25	2.99	1.25	1.84	3.85	3.91	1.39	2.57	5.67	0.66
No. 19....	0.59	0.51	1.78	5.43	4.57	3.18	2.83	1.01	4.45	3.84	3.18	1.83	1.19	1.82	2.58	1.85	1.21	3.04	2.96	4.09	2.51	1.27	1.91	1.72	2.47	2.17	2.89	1.23	1.77	3.60	3.64	1.23	2.45	5.43	0.51
No. 35....	0.75	0.63	1.95	5.47	4.80	3.15	2.85	0.91	4.79	3.95	3.20	1.81	1.20	2.09	2.67	1.96	1.20	3.09	3.05	4.26	2.58	2.02	2.03	1.87	2.64	2.23	3.05	1.36	1.84	3.72	3.81	1.30	2.57	5.47	0.63
No. 37....	0.83	0.77	1.85	5.50	4.70	3.26	2.95	1.16	4.36	3.93	3.19	1.88	2.39	1.23	2.80	1.85	1.30	3.19	3.04	3.91	2.64	2.57	1.96	1.70	2.86	3.40	2.97	1.34	1.88	3.70	3.77	1.19	2.63	5.50	0.77
Aver. value	0.77	0.67	1.88	5.51	4.56	3.18	2.79	1.01	4.58	3.87	3.14	1.88	1.56	1.91	2.66	1.96	1.24	3.07	3.00	4.06	2.51	1.87	2.01	1.85	2.60	2.49	2.94	1.34	1.83	3.67	3.67	1.26	2.54	5.29	0.67
High value	0.90	0.80	2.01	5.67	4.80	3.26	2.95	1.16	4.91	4.01	3.20	2.10	2.39	2.22	2.80	2.10	1.30	3.19	3.14	4.34	2.64	2.57	2.10	2.10	2.86	3.40	3.05	1.50	1.88	3.85	3.91	1.39	2.76	**5.51**	**0.67**
Low value.	0.59	0.51	1.78	5.43	4.0	3.10	2.60	0.95	4.36	3.60	3.03	1.80	1.19	1.23	2.50	1.85	1.20	2.90	2.80	3.70	2.40	1.27	1.91	1.70	2.50	2.17	2.80	1.23	1.77	3.50	3.20	1.19	2.19	.....	.....

SULPHURIC ANHYDRIDE (SO_3)

No. 10....	1.70	1.60	1.70	1.80	1.90	1.40	2.0	1.70	1.40	1.50	1.70	1.70	1.90	1.60	1.70	1.50	1.70	1.40	1.70	1.90	1.90	1.70	2.0	1.90	1.40	1.70	2.0	1.90	1.80	2.0	2.0	1.70	1.73	2.0	1.40
No. 16....	1.67	1.72	1.82	1.87	1.88	1.40	2.10	1.80	1.43	1.63	1.75	1.52	1.92	1.55	1.65	1.39	1.76	1.35	1.68	2.06	1.91	1.63	2.06	1.90	2.32	1.40	2.00	1.87	1.74	2.00	2.01	1.79	1.77	2.32	1.35
No. 19....	1.51	1.47	1.58	1.71	1.76	1.57	1.88	1.64	1.45	1.59	1.69	1.52	1.75	1.60	1.72	1.37	1.73	1.38	1.51	1.85	1.77	1.60	1.95	1.73	2.09	1.37	1.68	1.67	1.44	1.78	1.92	1.61	1.65	2.09	1.38
No. 35....	1.62	1.69	1.73	1.87	1.87	1.54	1.97	1.77	1.39	1.65	1.72	1.45	1.89	1.59	1.71	1.43	1.76	1.33	1.59	2.02	1.88	1.95	1.97	1.79	2.20	1.35	1.99	1.81	1.75	1.85	1.96	1.68	1.74	2.20	1.33
No. 37....	1.57	1.66	1.72	1.83	1.85	1.54	1.93	1.84	1.34	1.60	1.68	1.41	1.78	1.58	1.63	1.53	1.58	1.29	1.59	2.00	1.70	1.50	1.71	1.88	1.99	1.30	1.90	1.80	1.64	1.77	2.02	1.70	1.68	2.02	1.29
Aver. value	1.61	1.63	1.71	1.82	1.85	1.49	1.98	1.75	1.40	1.59	1.71	1.52	1.85	1.58	1.68	1.44	1.71	1.35	1.61	1.97	1.83	1.68	1.94	1.84	2.00	1.42	1.91	1.81	1.67	1.88	1.98	1.70	1.72	2.13	1.35
High value	1.70	1.72	1.82	1.87	1.90	1.57	2.10	1.84	1.45	1.65	1.75	1.70	1.92	1.60	1.72	1.53	1.76	1.40	1.70	2.06	1.91	1.95	2.06	1.90	2.32	1.70	2.0	1.90	1.80	2.0	2.02	1.79	1.82	**2.00**	**1.35**
Low value.	1.51	1.47	1.70	1.71	1.76	1.40	1.88	1.64	1.34	1.50	1.68	1.41	1.75	1.55	1.63	1.37	1.58	1.29	1.51	1.85	1.70	1.50	1.71	1.73	1.40	1.30	1.68	1.67	1.44	1.77	1.92	1.61	1.59	.....	.....

LOSS ON IGNITION

No. 10....	1.50	1.60	1.20	1.60	1.20	1.20	1.50	1.10	1.30	1.40	1.70	1.40	1.0	1.10	1.30	1.80	1.0	1.20	1.60	2.60	1.30	1.0	0.90	0.90	1.40	1.20	1.20	0.90	2.10	1.40	0.90	0.80	1.30	2.60	0.80
No. 16....	1.45	1.65	1.45	2.03	1.90	1.54	2.50	2.35	1.72	1.56	3.24	1.63	1.40	1.57	1.80	2.24	1.80	1.75	1.88	3.13	1.84	1.30	1.36	1.93	1.56	1.84	2.05	1.60	2.32	1.46	1.37	1.13	1.82	3.24	1.13
No. 19....	1.35	1.45	1.27	1.72	1.18	1.12	1.51	1.12	1.46	1.32	1.58	1.36	1.00	1.30	1.40	1.76	1.36	1.80	1.55	2.72	1.38	1.16	1.14	1.12	1.26	2.48	1.30	2.15	2.03	2.05	1.00	0.83	1.48	2.72	0.83
No. 35....	1.38	1.57	1.30	1.79	1.12	1.23	1.38	1.13	1.52	1.43	1.77	1.29	0.98	1.25	1.54	1.90	1.07	1.48	1.77	2.96	1.48	1.03	1.09	1.07	1.38	1.37	1.37	1.03	2.19	1.35	1.00	0.87	1.41	2.96	0.87
No. 37....	1.50	1.65	1.41	1.92	1.30	1.30	1.40	1.27	1.71	1.55	1.80	1.46	1.18	1.44	1.56	1.90	1.00	1.44	1.85	2.95	1.76	1.28	1.23	1.24	1.50	1.38	1.40	1.00	2.22	1.38	1.18	1.00	1.50	2.95	1.00
Aver. value	1.44	1.58	1.33	1.81	1.34	1.28	1.66	1.39	1.54	1.45	2.02	1.43	1.11	1.33	1.52	1.92	1.25	1.53	1.73	2.87	1.55	1.15	1.14	1.25	1.42	1.65	1.46	1.34	2.17	1.53	1.09	0.93	1.50	2.89	0.93
High value	1.50	1.65	1.45	2.03	1.90	1.54	2.50	2.35	1.72	1.56	3.24	1.63	1.40	1.57	1.80	2.24	1.80	1.80	1.88	3.13	1.84	1.30	1.36	1.93	1.56	2.48	2.05	2.15	2.32	2.05	1.37	1.13	1.88	**2.87**	**0.93**
Low value.	1.35	1.45	1.20	1.60	1.12	1.12	1.38	1.10	1.30	1.32	1.70	1.29	0.98	1.10	1.30	1.76	1.00	1.20	1.55	2.60	1.30	1.0	0.90	0.90	1.26	1.20	1.20	0.90	2.03	1.35	0.90	0.80	1.28	.....	.....

INSOLUBLE RESIDUE

No. 10....	0.30	0.30	0.40	0.20	0.20	0.20	0.20	0.30	0.20	0.30	0.20	0.20	0.10	0.30	0.30	0.30	0.10	0.10	0.20	0.30	0.20	0.30	0.10	0.10	0.10	0.10	0.20	0.20	0.20	0.10	0.10	0.20	0.21	0.40	0.10
No. 16....	0.35	0.18	0.48	0.12	0.20	0.16	0.85	0.14	0.22	0.29	0.27	0.37	0.59	0.10	0.22	0.57	0.09	0.59	0.86	0.63	0.18	0.49	0.09	0.69	0.10	0.12	0.14	0.06	0.30	0.13	0.16	0.17	0.31	0.85	0.06
No. 19....	0.15	0.20	0.70	0.25	0.05	0.15	0.20	0.10	0.10	0.25	0.08	0.25	0.15	0.25	0.15	0.25	0.15	0.25	0.05	0.20	0.25	0.20	0.15	0.15	0.15	0.10	0.10	0.20	0.20	0.15	0.05	0.10	0.18	0.70	0.05
No. 35....	0.19	0.14	0.44	0.09	0.11	0.06	0.16	0.10	0.18	0.27	0.09	0.19	0.05	0.08	0.09	0.17	0.08	0.15	0.04	0.20	0.20	0.07	0.09	0.12	0.08	0.10	0.16	0.14	0.28	0.10	0.07	0.10	0.14	0.44	0.04
No. 37....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Aver. value	0.25	0.21	0.51	0.17	0.14	0.14	0.35	0.16	0.18	0.28	0.16	0.25	0.22	0.18	0.19	0.32	0.11	0.27	0.29	0.33	0.21	0.27	0.11	0.27	0.11	0.11	0.15	0.15	0.25	0.12	0.10	0.14	0.20	0.60	0.06
High value	0.35	0.30	0.70	0.25	0.20	0.20	0.85	0.30	0.22	0.30	0.27	0.37	0.59	0.30	0.30	0.57	0.15	0.59	0.86	0.63	0.25	0.49	0.15	0.69	0.15	0.12	0.20	0.20	0.30	0.15	0.16	0.20	0.31	**0.86**	**0.11**
Low value.	0.15	0.14	0.40	0.09	0.05	0.06	0.16	0.10	0.10	0.25	0.09	0.19	0.05	0.08	0.09	0.17	0.08	0.10	0.04	0.20	0.18	0.07	0.09	0.10	0.08	0.10	0.10	0.06	0.20	0.10	0.05	0.10	0.12	.....	.....

NOTE.—Values in boldface figures are the high and low values of the averages.

TABLE II.—AVERAGE VALUES CHEMICAL AND PHYSICAL PROPERTIES; ALSO RATIOS AND POTENTIAL CONSTITUTION.

	Cements 1-32																																Average
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	
SiO	21.40	22.49	22.66	21.29	20.68	20.56	21.63	23.03	21.69	22.53	21.48	22.39	21.34	22.26	21.10	21.81	21.05	22.52	22.29	23.32	20.41	21.44	22.28	21.75	22.28	23.64	20.86	23.26	20.53	21.43	22.34	23.32	**21.92**
Fe_2O_3	2.99	4.44	2.84	2.70	3.04	3.43	2.51	3.09	2.14	2.25	2.90	4.56	3.09	2.28	2.52	3.06	4.14	2.63	2.21	1.89	2.58	2.55	3.24	2.67	2.17	1.83	2.84	3.63	3.52	2.41	3.39	3.68	**2.91**
Al_2O_3	6.86	3.63	6.52	5.83	6.24	5.57	7.08	6.02	6.04	6.22	5.81	4.16	7.28	6.00	6.88	6.44	6.19	5.64	6.09	4.25	7.13	6.45	5.58	5.93	6.34	4.82	7.45	5.64	5.41	6.52	4.54	5.06	**5.91**
R_2O_3	9.85	8.07	9.36	8.53	9.28	9.00	9.59	9.11	8.18	8.47	8.71	8.72	10.37	8.28	9.40	9.50	10.33	8.27	8.30	6.14	9.71	9.00	8.82	8.60	8.51	6.65	10.29	9.07	8.93	8.93	7.93	8.74	**8.82**
CaO	64.52	65.03	62.33	60.45	61.67	64.04	61.75	63.29	61.97	61.63	62.52	63.66	63.15	63.97	62.89	62.79	63.62	62.64	62.37	61.25	63.17	64.17	62.91	64.12	62.89	63.76	61.88	62.44	64.18	61.71	62.78	63.87	**62.92**
MgO	0.77	0.67	1.88	5.51	4.56	3.18	2.79	1.01	4.58	3.87	3.14	1.88	1.56	1.91	2.66	1.96	1.24	3.07	3.00	4.06	2.51	1.87	2.01	1.85	2.60	2.49	2.94	1.34	1.83	3.67	3.67	1.26	**2.54**
SO_3	1.61	1.63	1.71	1.82	1.85	1.49	1.98	1.75	1.40	1.59	1.71	1.52	1.85	1.58	1.68	1.44	1.71	1.35	1.61	1.97	1.83	1.68	1.94	1.84	2.00	1.42	1.91	1.81	1.67	1.88	1.98	1.70	**1.72**
Loss	1.44	1.58	1.33	1.81	1.34	1.28	1.66	1.39	1.54	1.45	2.02	1.43	1.11	1.33	1.52	1.92	1.25	1.53	1.73	2.87	1.55	1.15	1.14	1.25	1.42	1.65	1.46	1.34	2.17	1.53	1.09	0.93	**1.50**
Insoluble Residue	0.25	0.21	0.51	0.17	0.14	0.14	0.35	0.16	0.18	0.28	0.16	0.25	0.22	0.18	0.19	0.32	0.11	0.27	0.29	0.33	0.21	0.27	0.11	0.27	0.11	0.11	0.15	0.15	0.25	0.12	0.10	0.14	**0.20**
Total	99.59	99.47	99.27	99.41	99.38	99.55	99.40	99.58	99.36	99.54	99.58	99.60	99.38	99.33	99.25	99.42	99.20	99.38	99.30	99.61	99.18	99.31	99.10	99.41	99.70	99.61	99.34	99.26	99.31	99.15	99.79	99.82	**99.42**
$SiO_2 \div R_2O_3$	2.17	2.79	2.42	2.50	2.23	2.28	2.26	2.53	2.65	2.66	2.47	2.57	2.06	2.69	2.24	2.30	2.04	2.72	2.69	3.80	2.10	2.38	2.53	2.53	2.62	3.56	2.03	2.56	2.30	2.40	2.82	2.67	**2.49**
$Al_2O_3 \div Fe_2O_3$	2.29	0.82	2.30	2.16	2.05	1.62	2.82	1.95	2.82	2.77	2.60	0.91	2.36	2.63	2.73	2.10	1.50	2.15	2.76	2.25	2.76	2.53	1.72	2.22	2.92	2.63	2.62	1.55	1.54	2.71	1.34	1.38	**2.03**
$CaO \div SiO_2 + R_2O_3$	2.06	2.13	1.95	2.03	2.06	2.17	1.98	1.97	2.07	1.99	2.07	2.05	1.99	2.09	2.06	2.00	2.03	2.03	2.04	2.08	2.10	2.11	2.02	2.11	2.04	2.11	1.99	1.93	2.18	2.03	2.07	1.99	**2.05**
$3CaO \cdot SiO_2$	41.6	51.8	27.2	33.4	37.9	52.6	27.2	28.1	37.6	27.6	39.2	43.1	32.5	40.4	37.9	34.8	39.9	35.8	33.5	34.8	41.9	44.2	34.0	43.9	32.2	38.3	29.8	25.2	54.5	32.9	39.3	33.0	**37.5**
$2CaO \cdot SiO_2$	29.3	24.9	43.1	35.4	30.4	18.9	40.6	44.5	33.3	43.0	31.6	31.0	36.1	32.9	31.4	35.4	30.0	36.8	37.9	39.8	26.4	27.4	38.0	28.6	39.4	38.6	36.9	47.3	17.1	36.1	34.2	41.6	**34.2**
$3CaO \cdot Al_2O_3$	18.5	10.3	17.7	15.5	16.9	15.3	19.2	16.4	16.2	16.7	15.8	11.6	19.7	16.2	18.5	17.5	17.0	15.3	16.5	11.2	19.3	17.5	15.2	16.1	16.9	13.0	20.2	15.7	14.8	17.6	12.5	13.9	**15.7**
$2CaO \cdot Fe_2O_3$	4.8	6.9	4.4	4.4	4.8	5.3	3.9	4.8	3.3	3.8	4.5	7.1	4.9	3.6	4.0	4.7	6.4	4.1	3.4	3.3	4.1	4.0	5.1	4.2	3.5	2.9	4.4	5.7	5.5	3.8	5.3	5.7	**4.9**
$CaSO_4$	2.7	2.8	2.9	3.1	3.1	2.5	3.5	3.0	2.4	2.7	2.9	2.6	3.1	2.7	2.9	2.5	2.9	2.3	2.8	3.4	3.1	2.9	3.3	3.1	3.4	2.4	3.3	3.1	2.8	3.2	3.4	2.9	**2.9**
Silicates	70.9	76.7	70.3	68.8	68.3	71.5	67.8	72.6	70.9	70.6	70.8	74.1	68.6	73.3	69.3	70.2	69.9	72.6	71.4	74.6	68.3	71.6	72.0	72.5	71.6	76.9	66.7	72.5	71.6	69.0	73.5	74.6	**71.7**
Lime-Silicate Index	2.31	2.38	2.13	2.21	2.27	2.45	2.15	2.13	2.27	2.15	2.28	2.29	2.20	2.29	2.28	2.22	2.28	2.23	2.21	2.21	2.34	2.34	2.20	2.33	2.20	2.25	2.18	2.09	2.47	2.21	2.27	2.17	**2.25**
Initial Time of Set	3.04	4.38	3.07	4.20	3.37	3.49	3.35	4.10	3.41	4.22	4.02	2.47	4.00	4.20	4.19	3.45	3.51	3.55	4.15	3.24	3.58	2.50	4.00	3.07	1.54	3.58	3.51	3.18	3.25	3.42	2.07	3.54	**3.37**
Final Time of Set	5.16	7.38	5.27	7.00	5.58	6.17	5.58	6.54	6.20	7.16	6.54	6.01	6.37	7.00	6.49	6.02	6.15	6.35	6.59	6.25	6.48	5.52	6.40	5.18	5.35	7.13	6.30	5.57	6.00	6.30	5.50	6.54	**6.23**
Consistency	24.3	25.0	23.7	23.6	24.1	24.2	23.4	23.9	22.8	23.2	23.0	23.6	24.2	23.4	22.1	23.4	23.1	23.7	22.4	22.8	23.7	23.5	23.1	23.0	22.6	23.4	23.2	21.7	23.5	22.8	22.2	23.4	**23.3**
Residue 200 Sieve	12.9	6.8	9.9	21.0	13.2	13.3	16.2	15.7	14.3	15.7	16.7	11.9	12.1	14.0	19.8	15.1	14.1	19.7	16.9	11.7	15.5	17.5	16.2	10.8	19.3	14.2	18.1	17.3	17.0	20.2	16.2	16.9	**15.4**
Tens. Str., Mortar, lb. per sq. in. 3 days	275	240	210	190	250	230	230	205	195	195	210	235	255	205	215	205	220	185	185	160	255	255	220	260	205	180	230	170	245	195	210	200	**215**
7 days	350	330	260	260	315	310	310	285	290	255	295	305	330	285	290	270	290	260	260	235	325	325	285	335	270	265	290	230	325	265	275	265	**290**
28 days	445	440	375	370	395	400	405	405	380	375	390	390	430	400	385	375	385	375	375	360	405	410	390	405	390	375	380	345	420	365	380	375	**390**
Tens. Str., Neat., lb. per sq. in. 3 days	250	220	185	175	240	210	210	180	185	165	205	220	230	185	210	185	195	160	180	160	245	230	210	250	200	170	220	150	240	205	215	190	**200**
7 days	355	320	270	240	325	305	320	305	310	265	305	300	320	285	320	280	300	265	280	240	350	340	300	385	285	270	310	210	325	290	270	260	**295**
28 days	475	445	410	425	495	465	490	450	450	410	465	420	465	455	480	435	445	435	450	390	485	460	455	495	425	455	420	365	480	440	405	420	**445**
Compr. Str., Neat Cubes, lb. per sq. in. 3 days	2300	1650	1600	1180	1970	1550	1800	1340	1480	1150	1490	1640	1800	1380	1790	1390	1810	1170	1400	1090	2120	2100	1600	2070	1530	1190	1970	1090	1780	1630	1570	1330	**1590**
7 days	4080	2860	2810	1950	3230	2550	3400	2410	3070	2100	2540	2450	3140	2640	3280	2440	3200	2340	2540	1790	3500	3780	2500	3540	2420	2070	3030	1740	2640	2790	2150	2030	**2720**
28 days	7160	4920	5720	3900	5730	5400	6200	5300	5380	4900	5070	4110	6330	6000	6660	5000	6680	5540	5500	3680	5910	6630	4820	5560	4980	4330	4980	4000	4490	5100	4050	4150	**5230**
Compr. Str., 6 x 12-in. Cyl., lb. per sq. in. 3 days	1610	1270	1150	880	1370	1300	1080	1010	880	880	1070	1160	1340	1060	1170	1090	1270	880	1020	820	1460	1470	1180	1240	1040	710	1160	680	1180	940	1040	920	**1100**
7 days	2840	2200	1940	1490	2360	2200	1900	1690	1870	1570	2000	1960	2140	1880	1820	1850	2170	1490	1670	1230	2220	2430	1750	2190	1540	1220	1740	1190	1960	1610	1530	1530	**1850**
28 days	4000	3500	3200	2610	3550	3430	3220	3200	3090	2820	3240	2960	3700	3270	3290	3140	3660	2940	2880	2360	3400	3880	3040	3390	2850	2140	2750	2370	3260	2840	2950	2870	**3120**

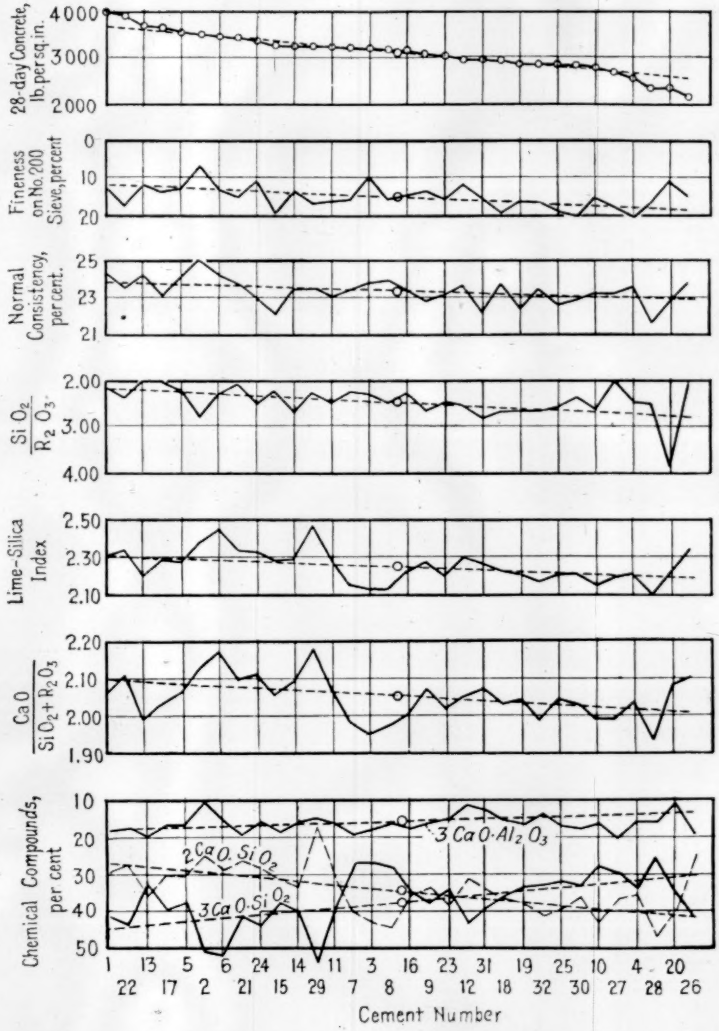

FIG. 1.—Relation of Concrete Strength to Fineness, Normal Consistency and Chemical Composition.

REPORT OF SUB-COMMITTEE III ON FINENESS

Sub-Committee III on Fineness has studied the data of the fineness determinations in the "Cooperative Tests of 32 Portland Cements by 47 Laboratories" sponsored by Sub-Committee VII and this report covers the principal facts shown by the fineness tests.

DATA AND DISCUSSION OF FINENESS TESTS

A study of the fineness determinations as reported to Sub-Committee VII by 44 of the cooperating laboratories and tabulated in Table I of this report, reveals a fairly satisfactory degree of concordance in the results. This statement is particularly true of the *average* values for the individual cements obtained by the five different groups of laboratories.

However, an examination of the individual determinations reported by the different laboratories reveals a considerable range in the residues on the No. 200 sieve. Out of about 1400 determinations reported to the committee, approximately 200, or slightly more than 14 per cent, differ from the grand average values from all laboratories by more than 2 per cent in the residues. The majority of these results which are most out of line with the grand averages were submitted by a comparatively small number of laboratories, this fact suggesting that the discordant results were largely due to systematic errors of some sort.

In an endeavor to ascertain whether some explanation for the consistently erratic results might not be found, inquiries were sent to all laboratories whose returns showed that eight or more of their fineness determinations differed from the grand average values by more than 2 per cent. There were ten such laboratories, and those in charge were asked to aid the committee by submitting answers to the following questions:

1. Is the sieve which was used in making these tests a certified sieve bearing the U. S. Bureau of Standards seal?
2. Does the sieve have a "correction" to the sieving value determined by test of standard fineness samples, and was the correction applied to the results obtained?
3. Has the operator who made the tests had considerable experience in making fineness tests; in other words, is he rated as a skilled operator?
4. Did the operator in making the tests follow substantially the procedure outlined in the Manual of Cement Testing appended to the Standard Specifications C 9 - 26?

5. Have you any comments to offer on the results of the tests, not covered by answers to the foregoing questions?

Without exception, all the laboratories addressed submitted answers to these questions. In four cases the answers to the first four questions enumerated above are affirmative, and for the present no explanation of the discordant results is apparent. In the remaining six cases, erratic values can be more or less completely accounted for. None of these six laboratories used certified sieves for these tests and four of them did not use corrections determined from calibration tests on cements of known fineness. In two cases, and possibly in several others, the experience of the operator in making fineness tests was either limited or not clearly indicated. In at least four cases the procedure set forth in the "Manual of Cement Testing" was not followed.

From the information obtained in connection with these tests, the sub-committee has gained the impression that erratic fineness results were mainly due to the use of uncalibrated sieves and failure to follow in detail the specified procedure, and in addition there is very definite evidence that operators in some of our best known laboratories are not using calibrated sieves, and either are not properly instructed in the art of making fineness tests, or else they are heedless of important precautions which must be taken in tests of this sort.

In conclusion, the committee would call attention to the fact that with one or two exceptions these 32 cements, selected at random from dealers' stocks throughout the country, range fairly evenly in fineness from 80 per cent to 90 per cent passing the No. 200 sieve, with an average value of 84.6 per cent. This average is nearly 7 per cent higher than the minimum requirement of the A.S.T.M. Standard Specifications and Tests for Portland Cement (C 9 - 26).

Respectfully submitted on behalf of the sub-committee,

J. C. PEARSON,
Chairman.

TABLE I.—FINENESS TESTS OF CEMENTS.

[Tests made in accordance with A.S.T.M. Standard Specifications and Tests for Portland Cement; Serial Designation C 9-26.

Laboratory	Residue on No. 200 sieve, per cent, Cements 1-32																																Average Value	High Value	Low Value	Difference
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32				
COMMERCIAL TESTING LABORATORIES																																				
No. 1	13.6	6.1	11.0	14.9	12.7	13.5	17.5	16.0	15.1	14.8	16.9	12.7	14.2	14.4	21.8	14.7	13.9	19.1	17.0	12.6	15.5	16.7	16.0	12.3	19.9	13.6	17.8	17.0	16.9	19.7	16.4	16.5	15.3	21.8	**6.1**	**15.7**
No. 3	10.7	6.6	9.8	20.1	11.9	12.8	15.4	14.0	14.1	15.9	16.9	12.0	11.9	16.1	19.9	15.1	13.0	19.2	17.1	11.8	16.3	17.0	16.9	11.2	21.0	14.8	19.9	19.9	16.9	20.4	16.8	20.0	15.5	21.0	**6.6**	**14.4**
No. 4	13.0	7.1	9.9	21.6	12.7	13.9	13.3	14.9	14.6	16.2	16.9	13.1	13.8	14.6	14.4	15.6	14.0	22.0	10.6	11.3	15.5	17.4	16.8	10.8	19.5	14.3	18.0	18.5	17.0	18.7	17.9	17.4	15.1	22.0	**7.1**	**14.9**
No. 5^a	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
No. 6	13.0	7.2	9.8	22.0	13.4	13.2	16.2	15.4	14.8	15.6	17.2	12.6	12.2	14.6	20.8	15.0	15.0	20.3	17.0	13.4	16.0	17.4	16.4	12.6	21.0	13.6	19.4	18.4	17.4	20.2	17.4	17.6	15.8	22.0	**7.2**	**14.8**
No. 7	12.2	7.5	9.8	21.2	12.5	13.3	16.5	16.5	14.4	16.6	17.3	12.3	12.8	15.1	19.1	15.5	13.9	19.9	18.3	11.3	16.5	18.7	17.4	11.2	19.6	14.7	18.4	17.1	17.6	24.6	16.1	17.9	15.8	24.6	**7.5**	**17.1**
Average value	12.5	6.9	10.1	20.0	12.6	13.4	15.8	15.4	14.6	15.8	17.0	12.5	13.0	15.0	19.2	15.2	14.0	20.1	16.0	12.1	16.0	17.4	16.7	11.6	20.2	14.2	18.7	18.2	17.2	20.7	16.9	17.9	15.5	22.3	**6.9**	**15.4**
High value	13.6	7.5	11.0	22.0	13.4	13.9	17.5	16.5	15.1	16.6	17.3	13.1	14.2	16.1	21.8	15.6	15.0	22.0	18.3	13.4	16.5	18.7	17.4	12.6	21.0	14.8	19.9	19.9	17.6	24.6	17.9	20.0	16.7	**20.2**	**6.9**	....
Low value	10.7	6.1	9.8	14.9	11.9	12.8	13.3	14.0	14.1	14.8	16.9	12.0	11.9	14.4	14.4	14.7	13.0	19.1	10.6	11.3	15.5	16.7	16.0	10.8	19.5	13.6	17.8	17.0	16.9	18.7	16.1	16.5	14.3	....	....	....
Difference	2.9	1.4	1.2	7.1	1.5	1.1	4.2	2.5	1.0	1.8	0.4	1.1	2.3	1.7	7.4	0.9	2.0	2.9	7.7	2.1	1.0	2.0	1.4	1.8	1.5	1.2	2.1	2.9	0.7	5.9	1.8	3.5	2.4	....	....	....
Difference, per cent of Average	23.2	20.3	11.9	35.5	11.9	8.2	26.6	16.2	6.8	11.4	2.4	8.8	17.7	11.3	38.5	5.9	14.3	14.4	48.1	17.3	6.2	11.5	8.4	15.5	7.4	8.4	11.2	15.9	4.1	28.5	10.6	19.6	15.5	....	....	....
GOVERNMENT, STATE AND MUNICIPAL LABORATORIES																																				
No. 9	13.0	6.9	9.1	21.0	13.0	13.7	15.9	16.0	14.9	15.8	16.4	12.4	12.6	13.9	20.7	16.0	14.2	20.0	18.5	12.1	16.8	17.7	17.3	11.9	20.6	15.0	18.5	18.2	17.5	21.1	17.4	17.8	15.8	21.1	**6.9**	**14.2**
No. 10	11.8	5.6	8.6	20.0	12.6	12.2	16.6	15.0	13.2	13.4	16.4	10.4	11.8	12.4	20.0	14.0	13.8	19.2	17.6	10.6	16.8	16.0	17.0	9.4	17.8	14.6	20.2	17.4	18.4	18.6	16.0	14.8	14.7	20.2	**5.6**	**14.6**
No. 11	12.9	5.9	9.6	20.1	12.6	13.1	15.7	14.9	13.9	14.7	15.8	11.0	11.8	13.1	18.6	14.0	13.2	18.9	16.1	10.3	15.8	16.4	15.6	10.3	19.0	13.2	17.4	17.1	16.1	19.1	15.4	16.5	14.6	20.1	**5.9**	**14.2**
No. 12	13.1	6.2	9.5	21.3	13.5	13.8	17.0	16.0	14.5	16.2	17.0	11.5	11.8	13.4	20.0	15.2	13.6	20.4	18.2	11.3	16.0	17.4	16.7	11.4	19.3	14.9	18.4	18.8	17.2	21.9	15.9	17.1	15.6	21.9	**6.2**	**15.7**
No. 13	12.8	7.3	10.3	21.8	13.4	13.2	16.9	15.8	14.6	15.2	16.4	11.2	12.2	15.2	21.0	15.6	13.5	19.8	16.9	11.2	16.4	18.0	17.5	11.4	19.6	15.5	19.8	17.7	18.2	21.3	19.6	18.4	15.9	21.8	**7.3**	**14.5**
No. 14	12.0	6.0	10.0	18.5	13.0	15.5	16.2	15.2	12.0	13.0	14.5	9.2	9.5	11.5	18.8	12.6	14.0	20.0	17.3	12.4	15.6	15.6	14.8	10.6	17.4	12.2	18.0	15.8	16.4	20.0	15.4	15.4	14.3	20.0	**6.0**	**14.0**
No. 15	13.5	7.5	9.8	21.1	13.1	13.5	16.3	15.8	14.0	15.6	16.7	12.4	12.5	13.6	19.7	15.2	13.8	19.2	17.5	11.4	16.5	17.2	16.3	11.4	20.0	13.6	18.2	17.9	17.3	20.1	16.4	16.7	15.4	21.1	**7.5**	**13.6**
No. 16	13.1	7.0	9.7	20.8	12.7	13.5	15.5	16.4	14.6	15.2	16.7	12.1	12.5	13.9	20.4	15.3	13.6	19.6	17.7	11.4	15.9	17.3	16.6	10.9	19.3	14.9	18.5	18.0	17.4	20.3	16.6	16.8	15.4	20.8	**7.0**	**13.8**
No. 17	12.8	6.9	7.3	20.8	12.8	13.5	16.0	15.4	14.3	15.3	16.5	12.6	12.4	13.9	20.1	15.1	14.2	19.5	17.3	11.2	17.5	17.2	15.8	10.9	19.7	14.3	17.9	17.5	16.9	20.9	15.9	17.1	15.3	20.9	**6.9**	**14.0**
No. 18^a	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
No. 19	14.1	6.2	12.0	24.1	14.0	14.4	18.5	16.8	14.8	18.2	18.3	12.5	14.2	14.6	20.8	16.8	16.0	20.7	18.5	12.0	16.6	18.3	16.7	10.8	20.7	16.0	18.5	18.8	18.3	22.3	18.3	18.3	16.6	24.1	**6.2**	**17.9**
No. 20	13.0	7.6	7.8	17.4	11.3	13.0	14.6	14.6	15.2	18.1	16.0	11.5	12.3	10.6	18.4	14.7	13.0	16.3	16.6	10.6	15.2	16.5	15.0	10.7	17.4	12.1	15.7	15.2	15.9	19.6	13.0	15.7	14.2	19.6	**7.6**	**12.0**
No. 21	15.6	8.8	12.8	25.0	17.0	15.6	20.8	17.0	15.6	18.0	19.8	14.4	13.6	14.6	22.0	15.8	14.8	20.2	18.2	11.4	16.6	18.2	16.8	13.2	20.0	14.4	19.8	18.6	18.2	21.8	17.8	18.6	17.0	25.0	**8.8**	**16.2**
No. 22	13.6	7.0	11.0	19.8	12.2	13.8	16.4	15.6	14.4	16.0	17.2	12.4	11.8	14.2	18.0	15.0	13.8	18.0	16.6	11.2	15.7	16.6	15.6	11.8	19.0	13.8	15.0	14.6	15.0	20.0	14.8	17.0	14.9	20.0	**7.0**	**13.0**
No. 23	12.4	6.3	8.8	20.4	11.7	10.9	15.3	14.4	13.2	14.5	14.8	11.6	11.2	13.0	19.5	10.6	12.5	19.5	17.0	19.3	14.0	14.7	14.8	9.9	20.0	13.7	17.0	15.9	16.0	19.8	13.8	16.6	14.5	20.4	**6.3**	**14.1**
No. 24	13.1	7.3	10.2	21.7	13.7	14.3	17.3	16.6	15.3	15.8	16.8	11.8	11.9	13.8	20.0	15.4	13.2	19.9	17.3	10.3	15.4	16.7	16.3	10.3	18.2	14.5	16.9	16.9	16.4	19.1	15.3	16.0	15.2	21.7	**7.3**	**14.4**
No. 25	13.1	7.8	10.7	20.8	9.9	13.6	14.4	13.1	13.5	12.4	15.1	11.7	10.5	12.8	19.5	12.2	13.4	19.4	14.5	10.3	14.9	14.6	13.0	10.4	19.1	11.9	17.8	15.2	16.9	18.2	13.9	17.6	14.1	20.8	**7.8**	**13.0**
No. 26	11.2	6.0	8.8	21.2	12.0	12.0	16.0	14.8	13.2	14.8	16.0	10.4	11.6	13.2	20.0	15.2	13.2	17.2	16.0	8.8	14.8	16.0	15.6	9.6	18.8	13.6	17.2	16.0	15.2	18.8	14.8	14.4	14.3	21.2	**6.0**	**15.2**
No. 27	12.8	7.0	9.1	22.2	13.4	14.4	17.6	17.4	15.6	16.8	18.0	12.2	13.6	15.6	21.4	16.4	14.4	21.4	19.4	12.0	17.2	18.6	18.0	12.0	21.2	16.0	20.2	18.2	18.4	22.0	17.8	18.2	16.5	22.2	**7.0**	**15.2**
Average value	13.0	6.9	9.7	21.0	12.9	12.8	16.5	15.6	14.3	15.5	16.6	11.7	12.1	13.5	19.9	14.7	13.8	19.4	16.3	11.5	16.0	17.7	16.1	10.3	19.3	14.1	18.0	17.1	17.0	20.3	16.0	16.8	15.2	21.2	**6.9**	**14.3**
High value	15.6	8.8	12.8	25.0	17.0	15.6	20.8	17.4	15.6	18.2	19.8	14.4	14.2	15.6	22.0	16.8	16.0	21.4	19.4	19.3	17.5	18.6	18.0	13.2	21.2	16.0	20.2	18.8	18.4	22.3	19.6	18.6	17.8	**21.0**	**6.9**	....
Low value	11.2	5.6	7.3	17.4	9.9	10.9	14.4	13.1	12.0	12.4	14.8	9.2	9.5	10.6	18.0	10.6	12.5	16.3	14.5	8.8	14.0	14.6	12.0	9.4	17.4	11.9	15.0	14.6	15.0	18.2	13.0	14.4	12.8	....	....	....
Difference	4.4	3.2	5.5	7.6	7.1	4.7	6.4	4.3	3.6	5.8	5.0	5.2	4.7	5.0	4.0	6.2	3.5	5.1	4.9	10.5	3.5	4.0	6.0	3.8	3.8	4.1	5.2	4.2	3.4	4.1	6.6	4.2	5.0	....	....	....
Difference, per cent of Average	33.8	46.4	56.7	36.2	55.0	36.7	38.8	27.6	25.2	37.4	30.1	44.4	38.8	37.0	20.1	41.5	25.4	26.3	30.0	91.3	21.9	22.6	37.2	36.9	19.7	29.1	28.9	24.6	20.0	20.2	41.2	25.0	32.9	....	....	....

PORTLAND CEMENT MANUFACTURERS LABORATORIES																																				
No. 28	13.3	7.2	9.9	21.4	13.1	13.2	16.8	15.7	14.3	15.5	16.1	10.4	14.9	14.1	19.5	14.8	14.2	20.2	17.6	10.2	15.2	15.9	15.6	10.4	18.3	14.1	16.6	16.0	15.2	17.3	15.6	15.4	15.0	21.4	**7.2**	**14.2**
No. 29	13.4	7.4	9.4	20.4	12.4	15.4	16.8	16.4	15.4	16.4	16.8	12.4	13.4	15.4	20.4	17.4	15.4	20.4	18.4	14.4	18.4	17.4	17.4	14.4	20.4	17.4	18.4	17.8	17.8	22.2	16.4	17.4	16.3	22.2	**7.4**	**14.8**
No. 30	12.4	6.6	9.5	20.6	12.2	13.4	16.0	15.5	14.0	15.2	16.4	12.3	11.6	13.5	19.4	15.0	13.2	18.6	16.7	15.8	15.2	16.4	15.9	10.2	19.4	13.7	17.8	17.6	16.8	19.4	15.7	16.6	15.1	20.6	**6.6**	**14.0**
No. 31	14.4	6.0	10.8	24.4	14.6	14.6	18.4	18.4	16.4	17.6	18.4	12.0	12.4	15.8	22.0	18.8	16.0	23.4	18.0	12.4	18.0	18.0	16.8	12.0	21.8	16.4	20.8	19.6	18.8	23.4	18.4	18.4	17.0	24.4	**6.0**	**18.4**
No. 32[a]	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
No. 33	12.2	6.8	8.8	20.8	13.2	14.4	16.8	15.2	15.6	16.4	15.6	10.4	11.2	14.0	20.8	14.8	13.6	20.4	17.2	11.2	16.4	17.6	16.4	11.6	18.4	14.4	16.4	17.6	17.2	20.8	16.8	17.6	15.3	20.8	**6.8**	**14.0**
No. 34	13.5	6.8	9.4	20.8	13.0	14.5	17.5	15.5	14.0	14.5	18.0	13.0	12.5	12.0	21.0	14.0	14.5	19.2	17.0	11.0	15.9	16.0	15.5	8.7	16.4	13.5	18.4	16.5	16.0	19.6	14.6	16.0	15.0	21.0	**6.8**	**14.2**
No. 35	13.0	6.2	9.9	22.0	13.5	14.2	17.4	16.4	15.0	16.5	17.8	11.8	12.9	14.6	20.4	16.0	14.4	21.0	18.3	12.0	17.4	18.4	17.6	12.4	19.6	15.2	19.4	18.2	17.8	21.3	16.8	18.3	16.2	22.0	**6.2**	**15.8**
No. 36	11.8	6.0	8.9	20.2	12.6	13.0	15.6	15.2	14.0	14.8	16.6	11.6	12.6	14.6	19.6	14.8	13.2	20.0	17.2	11.2	15.6	16.6	16.2	10.8	19.2	13.8	17.6	17.2	17.0	19.2	15.6	16.4	15.0	20.2	**6.0**	**14.2**
No. 37	12.5	7.0	10.2	21.0	13.6	13.4	14.4	16.0	14.0	15.6	17.0	12.2	12.0	14.5	20.2	15.0	14.8	19.2	18.0	10.8	16.5	18.0	14.4	11.7	18.7	14.4	17.0	17.6	16.6	20.3	16.0	16.7	15.3	21.0	**7.0**	**14.0**
No. 38	11.7	5.5	8.2	20.0	11.2	13.0	14.6	14.2	14.5	15.5	16.5	9.0	12.0	12.0	17.7	12.5	12.7	20.2	17.5	9.0	15.0	16.0	15.0	10.5	17.8	13.2	16.0	14.5	15.0	18.4	14.0	14.6	14.5	20.2	**5.5**	**14.7**
No. 39	12.4	7.4	10.4	21.8	14.2	14.8	18.2	16.8	15.4	17.0	17.8	12.2	13.4	15.2	21.2	16.4	14.4	21.2	18.8	12.0	17.0	17.8	17.6	11.6	20.0	15.4	18.8	18.0	18.0	20.8	17.0	17.4	16.3	21.8	**7.4**	**14.4**
No. 40	12.2	5.4	8.8	20.6	11.0	12.6	15.0	15.6	13.6	14.6	14.6	10.0	10.0	14.0	20.0	14.8	15.6	19.0	18.0	11.4	10.7	17.0	16.6	10.0	18.4	14.2	18.0	17.0	16.4	20.0	16.2	16.6	14.6	20.6	**5.4**	**15.2**
Average value	12.7	6.5	9.5	21.2	12.9	13.9	16.5	15.9	14.7	15.8	16.8	11.4	11.4	14.1	20.2	15.3	14.3	20.2	17.7	11.8	16.0	17.1	16.2	11.2	19.0	14.6	17.9	17.3	16.9	20.2	16.1	16.8	15.5	21.4	**6.5**	**14.9**
High value	14.4	7.4	10.8	24.4	14.6	15.4	18.4	18.4	16.4	17.6	18.4	12.4	14.9	15.8	22.0	18.0	16.0	23.4	18.8	15.8	18.4	18.4	17.6	14.4	21.8	17.4	20.8	19.6	18.8	23.4	18.4	18.4	17.5	**21.2**	**6.5**	....
Low value	11.7	5.4	8.2	20.0	11.0	12.6	14.4	14.2	13.6	14.5	14.6	9.0	10.0	12.0	17.7	12.5	12.7	18.6	16.7	9.0	10.7	16.0	14.4	8.7	16.4	13.2	16.0	14.5	15.0	17.3	14.0	14.6	13.4	....	....	....
Difference	3.7	2.0	2.6	4.4	3.6	2.8	4.0	4.2	2.8	3.1	3.8	3.4	4.9	3.8	4.3	5.5	3.3	4.8	2.1	6.8	7.7	2.4	3.2	5.7	5.4	4.2	4.8	5.1	3.8	6.1	4.4	3.8	4.1	....	....	....
Difference, per cent of Average	29.1	30.8	27.4	20.8	27.9	20.1	24.2	26.4	19.0	19.6	22.6	29.8	43.0	27.0	21.3	35.9	23.1	23.8	11.9	57.6	48.1	14.0	19.8	50.9	28.4	28.8	26.8	29.5	22.5	30.2	27.3	22.6	26.4	....	....	....
RAILROAD LABORATORIES																																				
No. 41	12.0	6.2	9.8	21.9	11.8	13.7	15.4	16.1	13.2	14.2	15.8	12.7	11.6	14.2	18.9	15.2	12.3	18.9	16.1	11.4	14.7	17.0	15.1	11.4	18.9	13.2	16.9	17.4	15.7	20.1	12.5	17.2	14.7	21.9	**6.2**	**15.7**
UNIVERSITY AND COLLEGE LABORATORIES																																				
No. 43	9.3	4.4	6.5	16.8	9.5	10.8	13.0	11.0	10.8	11.5	13.0	8.1	8.6	10.6	15.1	11.0	11.7	16.2	13.4	8.1	8.8	12.8	12.1	7.8	15.1	11.0	15.4	12.7	12.4	16.4	13.1	12.3	11.5	16.8	**4.4**	**12.4**
No. 44	13.2	7.0	9.8	21.9	13.3	14.3	17.0	16.6	14.9	17.2	17.6	12.5	12.5	14.9	20.5	15.6	14.7	20.9	18.3	11.7	16.7	17.7	17.7	11.4	20.3	15.2	18.8	17.8	17.6	21.7	16.9	17.2	16.0	21.9	**7.0**	**14.9**
No. 45	10.5	4.4	9.5	20.4	12.7	10.1	9.9	17.2	11.4	12.0	16.8	10.1	13.2	13.6	19.9	16.1	15.1	18.6	19.7	11.1	17.1	20.9	16.8	10.7	15.1	16.5	17.3	14.1	17.6	13.3	18.5	17.3	14.6	20.9	**4.4**	**16.5**
No. 47	14.0	6.2	13.6	19.2	12.3	13.4	16.9	15.2	14.8	14.9	16.9	11.5	13.6	14.2	19.5	14.1	14.4	18.7	17.0	12.2	16.8	16.7	16.8	10.6	19.5	13.5	18.5	16.8	16.8	19.5	17.5	15.7	15.4	19.5	**6.2**	**13.3**
No. 48	14.6	8.8	13.0	23.8	18.4	17.0	19.2	18.6	17.4	19.4	20.2	16.4	15.6	17.0	22.6	18.0	17.8	21.8	19.8	14.0	18.6	20.4	16.8	14.2	22.2	16.2	21.8	20.6	19.2	23.4	20.0	19.4	18.3	23.8	**8.8**	**15.0**
No. 49	12.5	6.0	9.5	20.3	11.9	13.3	15.6	15.1	13.8	15.2	16.0	12.1	11.3	14.3	19.0	14.3	13.1	18.0	16.2	10.6	15.8	16.5	15.5	9.7	18.5	13.1	18.2	17.3	16.1	20.6	15.5	16.1	14.7	20.6	**6.0**	**14.6**
No. 51	18.3	13.5	14.7	25.9	17.6	16.8	18.0	18.2	16.2	18.9	18.7	15.1	14.4	16.7	22.0	18.0	15.5	21.8	19.7	11.1	17.4	19.0	18.2	12.0	20.9	15.0	19.5	19.7	17.5	22.6	17.8	17.6	17.7	25.9	**11.1**	**14.8**
No. 52	11.8	5.7	8.6	20.2	11.8	12.2	15.4	14.7	13.0	19.4	16.1	12.6	11.5	14.6	19.1	14.3	14.6	18.4	15.4	14.0	15.2	16.4	16.0	11.5	20.8	11.8	17.4	18.4	19.6	19.4	16.9	16.0	15.1	20.8	**5.7**	**15.1**
Average value	13.0	7.0	10.6	21.1	14.7	13.5	15.6	15.8	14.1	16.1	16.9	12.3	12.6	14.5	19.7	15.2	14.6	19.3	17.4	11.6	13.5	17.5	16.2	11.0	19.1	14.1	18.3	17.2	17.1	19.6	17.0	16.5	15.4	21.2	**6.7**	**14.5**
High value	18.3	13.5	14.7	25.9	18.4	17.0	19.2	18.6	17.4	19.4	20.2	16.4	15.6	17.0	22.6	18.0	17.8	21.8	19.8	14.0	18.6	20.9	18.2	14.2	22.2	16.5	21.8	20.6	19.6	23.4	20.0	19.4	18.8	**21.1**	**7.0**	....
Low value	9.3	4.4	6.5	20.2	9.5	10.1	9.9	11.0	10.8	11.5	13.0	8.1	8.6	10.6	15.1	11.0	11.7	16.2	13.4	8.1	8.8	12.8	12.1	7.8	15.1	11.0	15.4	12.7	12.4	13.3	13.1	12.3	11.4	....	....	....
Difference	9.0	9.1	8.2	5.7	8.9	6.9	9.3	7.6	6.6	7.9	7.2	8.3	7.0	6.4	7.5	7.0	6.1	5.6	6.4	5.9	9.8	8.1	6.1	6.4	7.1	5.5	6.4	7.9	7.2	10.1	6.9	7.1	7.4	....	....	....
Difference, per cent of Average	69.2	130.	77.3	27.0	60.5	51.1	59.6	48.1	46.8	49.1	42.6	67.5	55.5	44.1	38.0	46.0	41.8	29.0	36.8	50.9	72.5	46.3	37.6	58.2	37.2	39.0	35.0	45.9	42.1	51.5	40.6	43.0	48.0	....	....	....
Grand Average Value	12.9	6.8	9.9	21.0	13.2	13.3	16.2	15.7	14.3	15.7	16.7	11.9	12.1	14.0	19.8	15.1	14.1	19.7	16.9	11.7	15.5	17.5	16.2	10.8	19.3	14.2	18.1	17.3	17.0	20.2	16.2	16.9	15.4	21.4	**6.7**	**14.7**
Grand High Value	18.3	13.5	14.7	25.9	18.4	17.0	20.8	18.6	17.4	19.4	20.2	16.4	15.6	17.0	22.6	18.0	17.8	23.4	19.8	14.0	18.6	20.9	18.2	14.4	22.2	17.4	21.8	20.6	19.6	24.6	20.0	20.0	18.9	**21.0**	**6.8**	....
Grand Low Value	9.3	4.4	6.5	14.9	9.5	10.1	9.9	11.0	10.8	11.5	13.0	8.1	8.6	10.6	14.4	10.6	11.7	16.2	10.6	8.1	8.8	12.8	12.0	7.8	15.1	11.0	15.0	12.7	12.4	13.3	13.0	12.3	10.9	....	....	....
Difference	9.0	9.1	8.2	11.0	8.9	6.9	10.9	7.6	6.6	7.9	7.2	8.3	7.0	6.4	15.2	7.4	6.1	7.2	9.2	5.9	9.8	8.1	6.2	6.6	7.1	6.4	6.8	7.9	7.2	11.3	7.0	7.7	8.0	....	....	....
Difference, per cent of Average	69.8	134.	82.9	52.4	67.5	51.9	67.3	48.4	46.1	50.3	43.1	69.8	57.9	45.7	76.7	49.0	43.3	36.6	54.4	50.5	63.2	46.3	38.2	61.1	36.8	45.0	37.6	45.6	42.4	56.0	43.2	45.5	52.0	....	....	....

NOTE.—Values in bold-face figures are the high and low values of the averages.

[a] Tests not made.

REPORT OF SUB-COMMITTEE V ON NORMAL CONSISTENCY

This report covers a study of the data of the A.S.T.M. normal consistency tests reported in the "Cooperative Tests of 32 Portland Cements by 47 Laboratories" sponsored by Sub-Committee VII.

DATA AND DISCUSSION OF NORMAL CONSISTENCY DETERMINATIONS

The data used in the preparation of this report are given in the accompanying Table I and Fig. 1. The information contained in the table and diagram was compiled from data reported to Sub-Committee VII in the "Cooperative Tests of 32 Portland Cements by 47 Laboratories."

The average percentage of water required for normal consistency for each of the various cements as determined by 45 laboratories is plotted in Fig. 1. The average normal consistency ranged from 22 per cent for 4 cements to 25 per cent for 1 cement. Seventeen cements had an average normal consistency of 23 per cent and ten cements an average normal consistency of 24 per cent. The average normal consistency for all cements was 23.3 per cent. Figure 1 also shows the maximum and minimum values of normal consistency as determined by any one laboratory. The range between maximum and minimum values obtained for the same cement by the various laboratories is one of the significant features of the tests. The largest variation was obtained for cement 25 where a minimum of 19.5 per cent and a maximum of 26 per cent were found, which means that 33 per cent more water was used by the one laboratory as compared with the other to obtain normal consistency with this cement. With a normal consistency of 19.5 per cent, a 1:3 standard sand mortar would require 9.7 per cent by weight of water according to Table I of the A.S.T.M. Standard Specifications and Tests for Portland Cement (C 9 - 26), while with a normal consistency of 26 per cent, the standard specifications would require 10.8 per cent of water by weight. In other words, one laboratory used 11.3 per cent more mixing water than another in the tests of 1:3 standard sand mortar from this cement. This difference in water content might be expected to account for some of the variations in the tensile strengths of the mortars. A study of the data with this point in view was made to see to what extent the differences in 1:3 briquet strength for a given cement could be explained by differences in water content.

In this study a tabulation was made of the 1:3 standard sand briquet strengths for each of the 32 cements at the different ages of test which were reported by those laboratories obtaining the high and low values of normal consistency in Table I. A study of the results on this basis showed that the briquet strengths for 12 of the 32 cements were generally appreciably higher in the tests of those laboratories reporting the low values of normal consistency than was the case in the tests of the laboratories reporting the high values of normal consistency. The briquet strengths obtained with the remaining 20 cements did not seem to have been influenced by differences in normal consistency. No doubt, other factors besides the normal consistency of the cement affected the results obtained, the exact effect of which it was not possible to evaluate. It appears then that even for extreme differences in the normal consistency determinations, there was generally no marked difference in the 1:3 briquet strengths obtained by the laboratories reporting high normal consistency values as compared with the strengths obtained by the

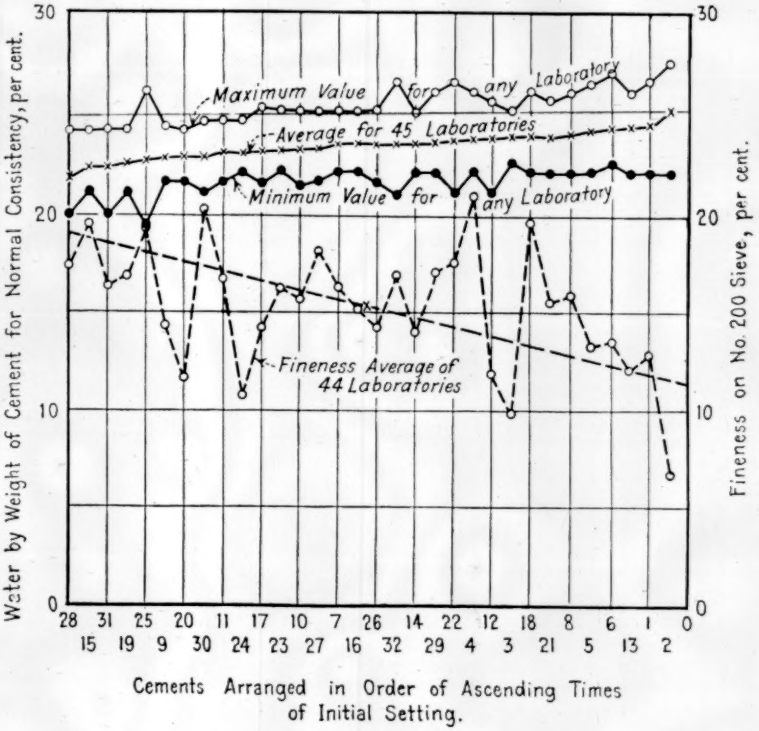

FIG. 1.—Range in Normal Consistency and Fineness of 32 Cements.

TABLE I.—NORMAL CONSISTENCY AND SOUNDNESS TESTS OF CEMENTS.

Tests made in accordance with the A.S.T.M. Standard Specifications and Tests for Portland Cement (Serial Designation: C 9 - 26).
All cements reported sound unless otherwise indicated.

Laboratory	NORMAL CONSISTENCY, PER CENT BY WEIGHT, CEMENTS 1-32																																Average Value	High Value	Low Value	Difference
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32				
COMMERCIAL TESTING LABORATORIES																																				
No. 1	23.5	24.0	23.5	24.5	24.5	24.0	24.0	24.5	23.0	23.5	23.0	23.5	24.0	23.5	22.0	23.0	23.5	23.5	24.0	23.0	23.0	22.5	23.5	23.0	19.5	23.5	24.0	22.5	23.5	22.0	22.5	23.0	23.3	24.5	19.5	5.0
No. 3	26.0	26.0	25.0	24.0	25.0	27.0	24.0	25.0	23.0	23.5	23.5	25.0	24.5	23.0	21.0	24.0	24.0	24.0	22.0	24.0	24.0	24.5	23.0	23.0	22.0	22.5	23.5	23.0	24.5	23.5	24.0	24.0	24.0	27.0	21.0	6.0
No. 4	23.5	25.0	23.0	23.0	23.5	23.0	23.0	23.0	22.5	23.0	22.0	22.5	22.5	23.0	22.5	24.0	23.0	24.5	23.0	23.0	23.5	23.0	22.5	23.0	22.0	24.0	23.0	22.0	24.0	23.0	22.0	22.5	23.0	25.0	22.0	3.0
No. 5[a]	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
No. 6	23.8	26.1	23.2	23.4	24.8[b]	25.6	23.9	23.9	23.0	23.0	23.4	24.3	24.1	23.5	21.4	23.7	23.2	23.2	22.2	23.8	23.6	24.1	23.2	23.3	22.4	22.8	23.8	21.2	23.5	22.6	20.6	24.2	23.4	26.1	21.2	4.9
No. 7	25.5	25.5	23.5	22.8	25.0	24.4	24.2	23.0	24.0	24.8	24.4	22.8	24.8	23.8	22.4	24.6	25.1	24.2	23.2	23.8	24.8	24.8	25.0	24.5	26.0	25.1	25.0	23.0	25.6	24.0	24.0	25.0	24.3	25.6	22.4	3.2
Average value	24.5	25.3	23.6	23.5	24.6	24.8	23.8	23.9	23.1	23.6	23.3	23.6	24.0	23.4	21.9	23.9	23.8	23.9	22.9	23.5	23.8	23.8	23.4	23.4	22.4	23.6	23.9	22.3	24.2	23.0	22.6	23.7	23.6	25.6	21.2	4.4
High value	26.0	26.1	25.0	24.5	25.0	27.0	24.2	25.0	24.0	24.8	24.4	25.0	24.8	23.8	22.5	24.6	25.1	24.5	24.0	24.0	24.8	24.8	25.0	24.5	26.0	25.1	25.0	23.0	25.6	24.0	24.0	25.0	24.8	25.3	21.9	....
Low value	23.5	24.0	23.0	22.8	23.5	23.0	23.0	23.0	22.5	23.0	22.0	22.5	22.5	23.0	21.0	23.0	23.0	23.2	22.0	23.0	23.0	22.5	22.5	23.0	19.5	22.5	23.0	21.2	23.5	22.0	20.6	22.5	22.6	....	....	....
Difference	2.5	2.1	2.0	1.7	1.5	4.0	1.2	2.0	1.5	1.8	2.4	2.5	2.3	0.8	1.5	1.6	2.1	1.3	2.0	1.0	1.8	2.3	2.5	1.5	6.5	2.6	2.0	1.8	2.1	2.0	3.4	2.5	2.2	....	....	....
GOVERNMENT, STATE AND MUNICIPAL LABORATORIES																																				
No. 9	23.6	25.0	24.0	23.8	24.2	24.8	24.0	24.4	23.2	23.6	23.2	24.4	24.6	23.6	22.8	23.6	23.6	24.4	22.8	23.0	24.0	24.2	23.8	23.6	22.8	23.8	24.0	22.4	24.0	24.4	23.6	25.0	23.8	25.0	22.4	2.6
No. 10	24.0	25.5	23.5	23.5	24.0	23.0	23.0	23.5	22.0	23.0	22.0	23.0	23.0	23.0	21.5	23.0	22.0	23.0	22.0	22.0	23.0	23.0	22.5	22.0	22.0	23.5	23.0	21.0	22.5	23.0	22.0	22.5	22.8	25.5	21.0	4.5
No. 11	23.5	24.0	23.0	23.5	24.0	23.0	23.0	23.5	23.0	23.0	23.0	23.0	24.0	23.0	22.0	23.0	23.0	24.5	22.0	22.0	23.5	23.0	23.5	23.0	22.0	22.5	23.0	21.5	23.0	23.0	22.0	23.5	23.0	24.5	21.5	3.0
No. 12	24.5	25.0	25.0	24.0	24.0	23.5	23.0	24.0	22.5	23.0	22.5	22.5	24.0	23.5	22.0	23.0	22.5	23.5	22.0	23.0	23.5	22.5	23.0	23.5	22.0	24.0	22.5	21.0	23.5	22.5	21.0	22.5	23.1	25.0	21.0	4.0
No. 13	22.5	23.0	23.0	22.0	22.0	23.0	22.0	22.5	21.5	21.5	21.5	23.0	22.0	22.0	21.0	22.5	21.5	22.0	21.5	21.5	22.0	21.0	22.0	22.0	24.0	22.0	22.0	21.0	23.0	22.0	22.0	22.5	22.1	24.0	21.0	3.0
No. 14	22.0	22.0	23.0	22.0	22.0	22.5	22.0	22.0	22.0	22.5	22.5	23.5	23.5	23.0	22.5	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	23.5	22.0	22.0	22.0	22.0	22.0	23.0	22.0	22.0	22.3	23.5	22.0	1.5
No. 15	24.0	26.0	23.5	23.5	24.5	24.0	23.5	24.0	22.5	23.0	23.0	23.5	24.5	23.5	22.0	24.0	23.0	23.5	22.3	23.0	23.5	24.0	23.0	23.0	21.5	22.5	23.0	21.0	23.5	23.0	21.0	24.2	23.2	26.0	21.0	5.0
No. 16	24.5	26.0	24.4	23.5	24.0	25.0	22.5	23.8	24.2	22.5	22.8	24.0	24.0	24.0	21.8	23.0	23.0	24.3	22.0	23.0	24.0	24.2	23.0	23.0	22.8	23.4	23.0	21.2	23.6	23.0	22.9	23.8	23.4	26.0	21.2	4.8
No. 17	24.0	25.0	24.0	24.0	24.0	24.0	23.0	24.0	23.0	24.0	23.5	24.0	24.0	23.5	22.0	23.5	23.0	23.5	23.0	23.0	23.5	24.0	23.0	23.0	22.0	23.5	23.5	21.5	23.0	23.0	22.5	23.0	23.4	25.0	21.5	3.5
No. 18[a]	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
No. 19	25.5	26.0	25.0	24.0	24.0	24.0	25.0	25.0	24.0	25.0	24.0	25.0	25.0	24.0	23.0	24.0	24.0	25.0	23.0	23.0	24.0	25.0	24.0	24.0	24.0	25.0	24.0	22.0	25.0	24.0	22.0	24.0	24.2	26.0	22.0	4.0
No. 20	23.0	23.5	23.5	23.0	23.0	23.5	23.0	23.0	23.0	23.0	22.5	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	22.5	22.5	23.0	22.5	23.0	23.0	23.0	23.0	23.0	23.5	22.5	1.0
No. 21	26.5	26.5	24.0	24.0	26.5	25.0	24.0	24.5	23.5	24.0	24.0	24.5	25.0	25.0	24.0	24.0	24.5	25.0	24.0	24.0	24.0	24.0	24.0	23.0	25.0	24.0	24.0	22.5	24.0	24.0	24.0	24.0	24.4	26.5	22.5	4.0
No. 22	23.5	24.0	23.5	23.5	23.5	23.0	23.0	23.5	22.5	23.0	23.0	23.5	24.0	22.5	22.0	23.0	23.0	23.5	22.5	22.5	23.5	23.0	22.5	23.0	21.5	23.0	23.0	21.5	23.0	22.5	21.0	22.0	22.9	24.0	21.0	3.0
No. 23	24.5	25.5	24.0	23.0	24.0	23.5	23.5	23.5	21.5	23.0	22.0	23.0	23.5	22.5	21.5	22.5	23.0	23.0	21.5	22.0	23.5	23.0	23.0	22.5	22.0	23.0	23.0	20.5	23.5	23.0	21.5	22.5	22.9	25.5	20.5	5.0
No. 24	25.0	26.0	24.0	24.0	25.0	25.0	24.0	25.0	24.0	24.0	24.0	24.0	25.0	21.0	22.0	24.0	24.0	24.0	22.5	23.0	24.0	23.0	24.0	23.0	23.0	23.5	24.0	22.0	24.0	23.0	23.0	24.0	23.8	26.0	22.0	4.0
No. 25	23.5	24.3	23.0	22.5	23.2	23.4	23.0	23.0	22.0	22.0	21.5	22.5	23.5	23.0	22.0	22.6	22.5	23.8	22.4	22.5	23.4	22.5	23.0	23.2	22.0	23.0	22.4	21.0	23.0	22.6	21.0	22.2	22.7	24.3	21.0	3.3
No. 26	25.0	27.0	23.0	24.0	24.0	26.0	24.0	24.0	22.0	23.0	24.0	24.0	25.0	23.0	22.0	23.0	23.0	24.0	22.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	21.0	23.0	23.0	23.0	24.0	23.4	27.0	21.0	6.0
No. 27	23.5	24.0	23.5	22.5	23.5	23.5	23.5	23.0	22.0	23.0	22.5	23.0	23.5	22.5	22.5	23.0	22.5	23.5	22.5	22.0	23.5	23.5	22.5	22.5	23.0	23.5	23.5	22.5	23.0	23.0	23.5	26.5	23.2	24.0	22.0	2.0
Average value	24.0	24.9	23.7	23.4	23.9	23.9	23.3	23.7	22.7	23.1	22.9	23.5	24.0	23.3	22.2	23.2	23.0	23.6	22.4	22.6	23.4	23.2	23.0	23.0	22.6	23.2	23.1	21.6	23.3	23.1	22.3	23.4	23.2	25.1	21.5	3.6
High value	26.5	27.0	25.0	24.0	26.5	26.0	25.0	25.0	24.2	25.0	24.0	25.0	25.0	25.0	24.0	24.0	24.5	25.0	24.0	24.0	24.0	25.0	24.0	24.0	25.0	25.0	24.0	22.5	25.0	24.4	24.0	26.5	24.8	24.9	21.6	....
Low value	22.0	22.0	23.0	22.0	22.0	22.5	22.0	22.0	21.5	21.5	21.5	22.5	22.0	22.0	21.0	22.0	21.5	22.0	21.5	21.5	22.0	21.0	22.0	22.0	21.5	22.0	22.0	21.0	22.0	22.0	21.0	22.0	21.8	....	....	....
Difference	4.5	5.0	2.0	2.0	4.5	3.5	3.0	3.0	2.7	3.5	2.5	2.5	3.0	3.0	3.0	2.0	3.0	3.0	2.5	2.5	2.0	4.0	2.0	2.0	3.5	3.0	2.0	1.5	3.0	2.4	3.0	4.5	3.0	....	....	....

Portland Cement Manufacturers' Laboratories

No. 28	23.0	25.0	23.0	23.0	23.4	23.0	23.4	24.0	23.0	23.0	22.4	22.6	24.0	24.0	22.0	23.6	23.0	24.0	22.8	23.0	23.6	22.4	23.0	23.0	22.0	24.0	22.0	20.0	23.0	22.0	21.0	22.0	22.9	25.0	20.0	3.3
No. 29	24.0	25.0	24.0	25.0	24.0	24.0	24.0	25.0	23.0	24.0	22.0	23.0	24.0	24.0	23.0	24.0	23.0	25.0	23.0	23.0	25.0	23.0	23.0	24.0	22.0	25.0	22.0	20.0	23.0	22.0	21.0	22.0	23.4	25.0	20.0	5.0
No. 30	24.0	25.0	24.0	23.2	24.0	23.5	23.5	24.0	23.5	24.0	23.5	23.0	24.0	22.5	22.5	23.5	23.0	24.0	23.0	23.5	23.5	22.5	23.0	23.5	21.5	24.5	21.5	21.2	23.0	21.5	21.5	22.0	22.2	25.0	21.2	3.8
No. 31	26.5	27.5	24.5	25.5	25.0	25.5	24.5	25.5	23.5	24.5	24.5	25.5	25.0	24.5	23.0	25.0	24.0	25.0	23.5	24.0	25.5	26.5	24.0	24.0	23.0	25.0	24.0	24.0	24.5	21.5	22.0	25.0	24.6	27.5	21.5	6.0
No. 32	25.0	26.5	24.5	24.5	24.0	25.5	23.8	24.5	22.5	24.0	23.5	24.5	24.5	24.0	21.5	24.0	22.5	23.5	21.5	22.0	24.0	24.0	23.0	22.5	23.5	23.0	23.0	21.2	23.8	22.8	22.5	23.5	23.5	26.5	21.2	5.0
No. 33	23.0	24.0	23.0	23.5	23.5	23.0	23.0	23.5	22.0	22.0	22.0	21.0	24.0	23.0	21.0	22.0	22.0	23.0	22.0	22.0	22.0	22.0	22.0	23.0	21.0	23.0	22.0	21.0	23.0	21.0	21.0	21.0	22.3	24.0	21.0	3.0
No. 34	24.0	25.0	24.0	23.0	24.0	24.0	23.0	23.0	23.0	23.0	23.0	23.0	24.0	24.0	23.0	24.0	24.0	23.0	23.0	24.0	24.0	23.0	23,0	24.0	22.0	24.0	23.0	22.0	23.0	22.0	22.0	23.0	23.3	25.0	22.0	3.0
No. 35	23.0	24.5	23.0	23.0	24.0	23.0	23.5	23.0	22.0	23.0	22.5	23.0	24.0	23.0	22.0	23.5	23.5	23.5	22.0	22.5	23.5	23.0	23.0	22.5	21.5	22.5	23.0	21.0	23.0	22.5	21.0	23.0	22.9	24.5	21.0	3.5
No. 36	24.5	24.0	22.5	23.0	23.5	23.5	22.5	23.0	22.0	23.0	23.0	25.0	24.0	23.0	21.0	23.0	23.5	22.5	22.5	22.0	23.0	23.0	23.0	22.0	23.0	21.5	22.5	21.5	23.0	22.5	21.5	23.0	22.8	25.0	21.0	4.0
No. 37	23.0	24.0	23.0	22.5	23.0	22.5	23.0	22.5	23.0	22.5	22.0	22.0	22.5	22.5	22.5	22.5	22.5	23.0	22.5	22.5	22.5	22.5	22.0	22.0	20.5	23.0	22.0	20.0	22.0	22.0	20.0	21.0	22.3	24.0	20.0	4.0
No. 38	23.5	25.0	24.0	24.5	24.0	24.0	23.5	24.0	23.0	23.5	23.0	22.5	24.0	23.5	23.0	23.5	23.5	24.0	22.5	23.0	24.0	24.0	23.0	23.0	22.0	23.0	23.0	22.0	24.0	24.0	22.0	23.5	23.4	25.0	22.0	3.0
No. 39	25.0	26.0	24.0	25.0	25.0	25.5	23.5	25.0	23.5	23.0	24.0	24.0	25.0	24.0	22.0	24.0	23.0	24.0	22.0	23.0	24.5	24.0	23.5	23.0	23.5	23.0	23.0	22.0	24.0	22.0	23.0	24.5	23.8	26.0	22.0	4.0
No. 40	26.0	26.0	24.0	26.0	26.0	24.0	24.0	26.0	24.0	23.0	24.0	24.0	26.0	25.0	23.0	25.0	24.0	26.0	23.0	24.0	25.0	25.0	25.0	23.0	23.0	24.0	24.0	22.0	26.0	24.0	23.0	25.0	24.5	26.0	22.0	4.0
Average value	24.2	25.2	23.7	24.0	24.1	23.9	23.5	24.1	22.9	23.2	23.0	23.3	24.2	23.6	22.3	23.6	23.2	23.9	22.6	23.0	23.8	23.5	23.1	23.0	22.2	23.5	22.7	21.4	23.5	22.2	21.6	23.0	23.2	25.3	21.2	4.1
High value	26.5	27.5	24.5	26.0	26.0	25.5	24.5	26.0	24.0	24.5	24.5	25.5	26.0	25.0	23.0	25.0	24.0	26.0	23.5	24.0	25.5	26.5	25.0	24.0	23.5	25.0	24.0	24.0	26.0	24.0	23.0	25.0	24.9	**25.2**	**21.4**	....
Low value	23.0	24.0	22.5	22.5	23.0	22.5	22.5	22.5	22.0	22.0	22.0	21.0	22.5	22.5	21.0	22.0	22.0	22.5	21.5	22.0	22.0	22.0	22.0	22.0	21.0	21.5	21.5	20.0	22.0	21.0	20.0	21.0	21.9	....	....	....
Difference	3.5	3.5	2.0	3.5	3.0	3.0	2.0	3.5	2.0	2.5	2.5	4.5	3.5	2.5	2.0	3.0	2.0	3.5	2.0	2.0	3.5	4.5	3.0	2.0	2.5	3.5	2.5	4.0	4.0	3.0	3.0	4.0	3.0	....	....	....

Railroad Laboratories

No. 41	24.5	25.0	23.5	24.0	25.0	24.0	23.5	24.0	22.5	23.0	23.0	23.5	24.5	24.0	22.0	24.0	23.5	23.5	22.0	23.0	24.0	24.0	23.0	24.0	22.0	25.0	23.5	21.0	22.5	22.5	20.0	22.0	23.3	25.0	20.0	5.0

University and College Laboratories

No. 43	25.0	25.5	25.0	22.5	24.0	23.0	23.0	25.0	22.5	22.5	23.5	24.5	25.0	22.5	21.0	23.5	22.0	24.0	21.0	23.0	24.0	24.5	24.0	22.0	23.5	22.0	23.5	23.5	24.5	23.5	23.5	24.5	23.5	26.5	21.0	4.5
No. 44	26.0	24.0	24.8	23.6	25.0	26.8	23.6	24.0	22.8	24.4	22.2	25.4	24.2	22.4	22.0	23.2	22.8	24.6	22.4	23.8	24.0	24.0	22.6	23.6	25.0	23.8	24.2	23.2	24.8	22.6	23.6	23.6	24.2	24.8	22.0	4.8
No. 45	23.4	23.6	23.0	24.0	23.6	24.4	23.2	23.2	22.2	23.6	22.4	23.4	23.2	23.0	23.6	23.0	22.2	23.0	22.0	23.4	23.6	23.6	23.0	22.0	22.0	23.0	22.0	22.0	23.0	23.0	22.0	23.0	23.0	24.4	22.0	2.4
No. 47	26.0	27.0	25.0	25.5	25.5	25.0	24.0	24.5	23.0	23.8	24.0	25.5	26.0	24.5	22.0	24.0	23.6	24.0	22.5	22.6	24.5	24.2	24.0	23.0	23.5	24.0	24.1	22.0	23.8	23.6	23.0	26.0	24.2	27.0	22.0	5.0
No. 48	25.0	26.0	24.0	25.0	25.0	26.0	24.0	24.0	22.0	23.0	23.0	24.0	25.0	23.0	22.0	23.0	23.0	23.0	22.0	22.0	24.0	25.0	22.0	23.0	23.0	23.0	24.0	21.0	24.0	23.0	24.0	24.0	23.6	26.0	21.0	5.0
No. 49	24.0	23.0	23.0	22.0	24.0	23.0	24.0	23.0	22.0	23.0	22.0	23.0	24.0	23.0	22.0	22.0	22.0	23.0	22.0	22.0	24.0	23.0	23.0	22.0	21.0	23.5	23.0	22.0	23.5	22.0	23.0	24.0	22.8	24.0	21.0	3.0
No. 51	25.0	24.0	24.0	22.0	23.5	26.0	23.0	23.0	22.0	23.0	22.0	25.5	24.0	22.0	21.0	23.0	23.0	23.0	21.0	22.0	23.5	24.5	23.0	23.0	23.0	22.0	23.0	21.0	23.0	23.0	22.0	22.0	23.0	26.0	21.0	5.0
No. 52	25.2	26.8	23[c]2	25.2	25.2	25.2	23.6	24.4	22.8	23.2	24.4	24.8	25[c]2	24.0	21.6	24[c]0	23[c]6	23.6	22.4	22[c]8	24[c]0	23[c]2	24.2	23.2	23.2	23.2	24[b]0	22[b]0	24.0	22.8	22.4	24[b]6	23.8	26.8	21.6	5.2
Average value	25.0	25.0	24.0	23.7	24.4	24.9	23.6	23.9	22.4	23.3	23.0	24.5	24.6	23.0	21.9	23.2	22.8	23.6	21.9	22.7	24.0	24.0	23.1	22.7	23.2	23.0	23.5	22.1	23.8	22.9	22.9	24.0	23.6	25.8	21.4	4.4
High value	26.0	26.8	25.0	25.5	25.5	26.8	24.0	25.0	23.0	24.4	24.4	25.5	26.0	24.5	23.6	24.0	23.6	24.6	22.5	23.8	24.5	25.0	24.2	23.6	25.0	24.0	24.2	23.5	24.8	23.6	24.0	26.0	24.6	**25.0**	**21.9**	....
Low value	23.4	23.0	23.0	22.0	23.5	23.0	23.0	23.0	22.0	22.5	22.0	23.0	23.2	22.0	21.0	22.0	22.0	23.0	21.0	22.0	23.5	23.0	22.0	22.0	21.0	22.0	22.0	21.0	23.0	22.0	22.0	22.0	22.4	....	....	....
Difference	2.6	3.8	2.0	3.5	2.0	3.8	1.0	2.0	1.0	1.9	2.4	2.5	2.8	2.5	2.6	2.0	1.6	1.6	1.5	1.8	1.0	2.0	2.2	1.6	4.0	2.0	2.2	2.5	1.8	1.6	2.0	4.0	2.2	....	....	....
Grand average value	24.3	25.0	23.7	23.6	24.1	24.2	23.4	23.9	22.8	23.2	23.0	23.6	24.2	23.4	22.1	23.4	23.1	23.7	22.4	22.8	23.7	23.5	23.1	23.0	22.6	23.4	23.2	21.7	23.5	22.8	22.2	23.4	23.3	25.3	21.3	4.0
Grand high value	26.5	27.5	25.0	26.0	26.5	27.0	25.0	26.0	24.2	25.0	24.5	25.5	26.0	25.0	24.0	25.0	25.1	26.0	24.0	24.0	25.5	26.5	25.0	24.5	26.0	25.1	25.0	24.0	26.0	24.4	24.0	26.5	25.2	**25.0**	**21.7**	....
Grand low value	22.0	22.0	22.5	22.0	22.0	22.5	22.0	22.0	21.5	21.5	21.5	21.0	22.0	22.0	21.0	22.0	21.5	22.0	21.0	21.5	22.0	21.0	22.0	22.0	19.5	21.5	21.5	20.0	22.0	21.0	20.0	21.0	21.5	....	....	....
Difference	4.5	5.5	2.5	4.0	4.5	4.5	3.0	4.0	2.7	3.5	3.0	4.5	4.0	3.0	3.0	3.0	3.6	4.0	3.0	2.5	3.5	5.5	3.0	2.5	6.5	3.6	3.5	4.0	4.0	3.4	4.0	5.5	3.7	....	....	....

NOTE.—Values in bold-face figures are the high and low values of the averages. [a] Tests not made. [b] Slight warping or distortion. [c] Cracking.

laboratories reporting low values of normal consistency on the same cements.

Based on the average of the high and low normal consistency values in Table I, there would be a difference of only 5 cc. in the amount of water used in making a 1000-g. batch of 1:3 mortar. Since the measurements of the water are probably only accurate to within ±2 cc., appreciable differences in briquet strength were not to be expected from this cause.

In order to determine if any relationship existed between the normal consistency and fineness of the cements, the average residues on the No. 200 sieve were plotted in Fig. 1. The relationship is not exact although the trend of the curves is consistent, that is, the finer the cement the greater the quantity of water required for normal consistency.

Studies were made to determine whether there was any consistent relationship between the normal consistency of the cement and flow of the concrete. These studies showed that no definite relationship existed. This is probably due to the fact that the cement in 1:2.4:3.6 mix is only about one-sixth of the total dry material and that, therefore, the differences in normal consistencies would not be great enough to have any appreciable effect on the flow of the concrete. There also appeared to be no definite relation between the normal consistency of a cement and the strength of the concrete made from that cement.

The wide range in results obtained in normal consistency tests by the different laboratories shows that more care must be exercised in following standard specifications if concordant results are to be secured. The differences in determinations of normal consistency are probably due in the main to the personal equations of the operators and to differences in the temperature and moisture conditions existing at the time the tests were made.

It would seem from the results obtained in this investigation that a standard normal consistency could be selected for all cements and thus eliminate one of the variables which enter into the testing of the cement without materially affecting the strengths obtained in tests of standard sand briquets. The effect of adopting this procedure on the strength, soundness and time of set should be investigated further.

Respectfully submitted on behalf of the sub-committee,

W. H. KLEIN,
Chairman.

REPORT OF SUB-COMMITTEE VI ON TIME OF SETTING

The work of Sub-Committee VI for the past few months has been devoted principally to a study of new methods of making time of setting tests with a view to developing a simpler and quicker method than the present A.S.T.M. standard. Methods tried included penetration tests on fluid cement pastes as well as on normal consistency pastes both with the standard 300-g. Vicat needle and a modified needle weighing 100 g. These studies have been carried out at the Research Laboratory of the Portland Cement Association on the 32 cements used in the cooperative investigation sponsored by Sub-Committee VII. In addition to these special tests, the sub-committee has studied the results of the time of setting tests as reported by 43 cooperating laboratories, a brief discussion of which is given below.

The results of time of setting tests on the 32 cements reported by 43 laboratories are given in Tables I and II and in Fig. 1. A study of these results showed very considerable variations and many apparent inconsistencies. The variations between the different cements is clearly seen in Fig. 1 which gives the times of setting for the 32 cements arranged in order of ascending time of initial set. The average initial time of setting for all laboratories ranged from 1 hour and 54 minutes to 4 hours and 38 minutes with a mean initial time of 3 hours and 37 minutes. If the four low values are omitted, it is seen that the difference between the quickest and the slowest is only about 1½ hours. The diagrams also show that the average final time of setting ranged from 5 hours and 16 minutes (cement 1) to 7 hours and 38 minutes (cement 2) with a mean of 6 hours and 23 minutes and a spread of about 2½ hours.

The great difference between the results for different laboratories is of more significance than the difference between the cements. In Fig. 1 are shown the lowest and highest values of initial and final time of setting for each cement as determined by individual laboratories. The spread between the average maximum and minimum values for initial set was about 4 hours and for final set about 6 hours. The greatest difference in time reported for initial set for a given cement varied from a minimum of 5 minutes to a maximum of 6 hours and 50 minutes. A few other cases showed almost as great a variation.

TABLE I.—INITIAL TIME OF SETTING OF CEMENTS.

Tests made in accordance with the A.S.T.M. Standard Specifications and Tests for Portland Cements (Serial Designation C 9 - 26).
Vicat needle used unless otherwise indicated.

Laboratory	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	Average Time	High Time	Low Time
	Initial Time of Setting, Cements 1-32																																		
	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
COMMERCIAL TESTING LABORATORIES																																			
No. 1	3 35	5 20	3 40	5 20	4 25	3 45	4 20	4 45	3 55	3 30	4 20	3 25	3 35	4 55	3 50	3 55	4 10	3 45	4 50	4 30	3 50	3 20	5 20	4 35	0 45	4 25	3 50	4 25	3 40	3 10	3 20	3 15	4 00	5 20	0 45
No. 3	3 55	6 00	3 45	4 45	3 35	7 05	4 55	6 20	4 45	5 50	5 30	6 15	4 35	5 50	3 55	4 35	4 20	5 00	5 05	5 45	5 40	4 55	5 55	3 25	3 35	5 05	5 05	8 05	5 25	5 50	3 45	6 45	5 10	8 05	3 25
No. 4	2 45	5 30	2 45	4 45	3 40	3 05	4 20	4 25	3 50	4 35	4 15	1 45	4 00	4 00	4 50	3 35	4 00	3 25	5 15	3 25	3 45	3 40	3 20	2 30	1 20	5 00	5 15	4 10	3 00	3 15	2 10	3 40	3 44	5 30	1 20
No. 5ᵃ	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
No. 6	2 50	5 15	2 15	4 35	3 46	5 05	3 40	4 25	3 00	3 50	4 05	1 05	3 50	4 30	4 05	3 30	3 45	3 45	3 35	3 00	3 55	3 15	2 55	4 10	0 25	3 55	3 55	3 15	3 10	3 40	0 55	4 15	3 30	5 15	0 25
No. 7	3 15	5 20	3 10	3 35	4 05	3 05	3 10	4 05	4 30	4 20	4 10	3 25	4 05	3 45	4 15	3 10	3 15	3 25	3 25	3 05	3 15	3 20	3 20	2 45	0 55	3 20	3 05	3 15	3 10	3 20	2 55	3 10	3 27	5 20	0 55
Average time	3 16	5 29	3 07	4 36	3 54	4 21	4 05	4 48	3 59	4 25	4 04	3 11	4 01	4 36	4 11	3 45	3 54	3 52	4 26	3 57	4 05	3 42	4 10	3 29	1 23	4 21	4 14	4 38	3 41	3 51	2 37	4 13	3 58	5 22	3 05
High	3 55	6 00	3 45	5 20	4 25	7 05	4 55	6 20	4 45	5 50	5 30	6 15	4 35	5 50	4 50	4 35	4 20	5 00	5 15	5 45	5 40	4 55	5 55	4 35	3 35	5 05	5 15	8 05	5 25	5 50	3 45	6 45	5 17	....	....
Low	2 45	5 15	2 15	3 35	3 35	3 05	3 10	4 05	3 00	3 30	4 05	1 05	3 35	3 45	3 50	3 10	3 15	3 25	3 25	3 00	3 15	3 15	2 55	2 30	0 25	3 20	3 05	3 15	3 00	3 10	0 55	3 10	3 02	....	....
GOVERNMENT, STATE AND MUNICIPAL LABORATORIES																																			
No. 9	3 15	5 10	3 20	5 20	3 55	5 05	3 45	4 15	3 40	4 25	4 00	4 40	3 15	4 20	4 10	3 40	3 45	3 55	4 15	2 35	3 20	3 30	5 15	2 55	1 30	4 15	4 40	4 00	3 40	5 15	0 50	6 00	3 55	6 00	0 50
No. 10	2 15	3 40	2 25	3 45	2 45	3 15	4 15	4 30	3 00	4 00	3 30	2 50	3 45	4 30	4 15	4 00	4 20	4 50	4 25	2 55	3 40	2 50	4 00	2 15	0 08	3 15	2 25	3 35	1 40	1 45	1 15	5 15	3 17	5 15	0 08
No. 11	3 15	4 00	2 45	4 45	3 45	1 45	3 45	4 45	3 45	4 45	4 30	1 45	3 15	4 45	3 30	3 45	4 00	4 45	4 45	2 30	3 45	1 45	4 30	3 45	1 30	3 30	4 45	1 30	3 30	4 30	1 15	1 15	3 30	4 45	1 15
No. 12	3 45	5 30	4 05	4 50	4 20	5 10	3 55	5 15	5 05	5 10	4 35	4 55	4 30	5 30	5 50	4 50	4 45	4 20	4 35	4 10	4 30	4 00	4 55	3 35	4 10	4 55	4 40	3 40	3 50	4 20	3 45	5 20	4 34	5 50	3 35
No. 13	1 55	4 05	1 20	2 20	3 20	3 50	2 45	3 25	2 15	2 50	3 30	3 40	2 55	3 05	3 35	3 30	2 50	3 10	3 05	3 25	2 20	2 00	2 00	3 00	0 20	2 55	1 45	2 45	3 40	2 15	2 20	3 05	2 47	4 05	0 20
No. 14ᶜ	2 30	3 00	4 00	4 00	3 30	3 30	3 15	3 45	4 15	5 45	3 45	3 30	4 00	5 30	4 15	3 30	3 45	4 00	3 15	5 00	3 45	....	4 15	3 00	5 00	5 15	4 00	2 30	3 45	3 45	5 30	6 00	4 00	6 00	2 30
No. 15	2 50	4 50	2 50	4 10	3 15	3 10	3 40	4 30	3 25	3 40	3 25	1 00	3 55	4 15	4 10	3 25	3 55	3 45	4 10	2 45	3 30	2 15	4 05	3 05	0 55	3 45	3 45	4 00	2 55	3 20	0 20	5 15	3 18	5 15	0 20
No. 16	3 00	5 15	3 45	4 15	3 30	5 45	3 00	4 15	3 25	0 45	3 45	0 25	3 45	4 00	3 30	3 45	4 00	3 30	4 30	4 00	4 00	4 15	4 00	3 15	3 30	3 30	4 15	5 00	4 00	5 00	5 00	4 15	3 50	5 45	0 25
No. 17	3 20	4 45	3 30	4 00	4 00	3 50	4 00	4 40	6 00	5 50	5 20	5 00	5 00	5 00	5 30	4 20	4 40	4 30	5 00	3 10	4 45	2 40	3 35	3 50	2 15	5 50	4 15	3 30	4 00	4 45	3 25	3 45	4 18	6 00	2 15
No. 18ᶜ	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
No. 19	2 55	4 15	2 50	4 00	3 05	2 40	2 50	3 25	3 15	3 55	3 20	3 50	3 25	3 40	3 50	3 25	3 45	3 35	4 10	2 45	3 10	3 00	4 05	2 50	2 40	4 25	3 55	3 55	3 45	4 30	1 05	5 10	3 23	4 30	1 05
No. 20	3 30	6 08	4 15	5 40	5 15	5 03	4 05	4 15	5 50	5 10	5 42	3 36	4 15	6 35	6 25	6 08	4 34	5 35	5 30	5 15	5 10	3 10	4 45	4 25	2 43	4 57	4 55	4 47	4 32	4 52	3 00	6 10	4 55	6 35	2 43
No. 21	3 16	3 52	3 03	3 36	3 58	4 11	3 29	4 16	3 36	4 20	4 03	2 56	3 15	4 10	4 13	3 33	3 51	4 48	5 30	3 56	4 49	2 57	4 17	3 34	0 28	3 41	4 20	0 59	3 00	4 10	0 34	4 24	3 36	5 32	0 28
No. 22	2 40	4 45	2 40	3 30	2 35	3 20	2 20	3 35	3 10	3 35	3 40	3 20	3 00	3 45	3 45	3 00	3 10	3 00	3 45	2 55	3 45	2 55	3 50	2 20	2 50	3 30	3 15	2 35	2 40	3 45	1 10	3 55	2 42	4 45	1 10
No. 23	3 10	4 40	2 55	4 25	3 15	3 30	4 00	4 30	3 40	5 00	3 10	0 25	4 35	4 20	5 10	4 00	3 20	3 45	4 30	3 50	4 00	2 50	4 35	2 55	0 30	4 30	4 10	2 40	2 25	3 05	1 20	4 45	3 33	5 10	0 25
No. 24	4 15	6 00	3 35	5 15	3 50	6 00	4 00	5 25	4 10	5 30	5 05	4 15	5 10	5 35	4 15	4 15	4 25	4 25	4 55	4 10	4 40	3 00	4 35	3 25	3 55	4 25	4 20	5 20	4 25	3 40	3 10	5 05	4 30	6 00	3 00
No. 25	2 45	3 50	3 20	3 53	3 20	3 03	3 55	5 05	3 20	4 18	4 05	4 00	3 50	5 10	4 33	3 38	3 40	3 30	4 05	4 25	4 15	2 35	3 45	2 20	2 10	2 55	3 30	2 30	3 05	4 00	3 05	3 15	3 36	5 10	2 10
No. 26	8 30	7 00	2 45	5 00	3 30	6 00	4 00	5 00	3 30	5 00	4 00	4 15	3 30	4 30	4 45	3 45	4 30	3 45	4 30	3 30	3 30	3 00	3 45	3 00	3 15	4 00	3 30	3 45	3 00	5 00	3 30	5 15	4 10	7 00	2 45
No. 27	2 35	3 45	3 00	3 15	3 00	2 40	2 26	2 55	2 50	3 35	3 00	3 00	3 10	3 00	2 55	2 35	2 40	3 50	3 20	3 00	3 00	2 00	3 15	2 15	2 50	2 45	2 10	3 00	2 45	3 45	3 50	3 00	2 56	3 50	2 00
Average time	3 02	4 42	3 08	4 13	3 34	2 59	3 31	4 19	3 47	4 19	4 01	3 11	3 48	4 32	4 22	3 50	3 53	4 03	4 21	3 34	3 53	2 52	4 05	3 17	2 16	4 01	3 49	3 20	3 22	3 59	2 28	4 31	3 43	....	....
High	4 15	7 00	4 15	5 40	5 15	6 00	4 15	5 25	6 00	5 50	5 42	5 00	5 10	6 35	6 25	6 08	4 45	5 35	5 30	5 15	5 10	4 15	5 15	4 25	5 00	5 50	4 55	5 20	4 30	5 15	5 30	6 10	5 22	7 00	4 15
Low	1 55	3 00	1 20	2 20	2 35	1 45	2 20	2 55	2 15	0 45	3 00	0 25	2 55	3 00	2 55	2 35	2 40	3 00	3 05	2 30	2 20	1 45	2 00	2 15	0 08	2 45	1 45	0 59	1 40	1 45	0 20	1 15	2 04	3 00	0 08

Portland Cement Manufacturers' Laboratories

No. 28	2 30	4 00	2 45	4 10	3 15	2 30	3 00	3 25	3 20	3 45	3 20	0 07	3 20	3 35	3 55	3 10	3 20	3 25	3 55	2 50	4 15	2 25	3 25	3 05	0 15	4 15	3 00	2 15	3 15	2 35	0 25	4 25	3 02	4 25	0 07
No. 29	2 50	3 10	3 20	4 25	3 20	2 50	3 55	2 50	3 30	4 10	3 20	0 15	4 10	3 55	4 20	3 00	4 00	4 25	4 35	3 00	4 45	2 45	3 55	3 10	0 45	3 50	4 00	2 10	3 00	3 50	0 25	0 30	2 57	4 45	0 15
No. 30[b]	3 55	5 00	4 45	5 00	4 45	4 50	5 10	4 40	4 45	5 50	5 10	4 15	5 45	5 25	6 05	5 30	4 55	5 30	5 25	5 00	4 45	4 30	4 40	4 25	3 55	6 05	4 15	4 15	4 50	4 35	3 10	5 15	4 52	6 05	3 10
No. 31	3 30	5 15	2 40	4 00	3 15	3 25	3 00	4 00	3 45	4 45	3 30	3 00	3 00	3 30	4 15	3 25	3 35	4 10	4 15	3 00	3 10	3 05	3 45	2 40	0 20	3 35	3 00	3 00	2 20	3 00	1 30	3 00	3 18	5 15	0 20
No. 32[a]	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
No. 33	1 55	3 15	1 55	4 05	3 05	1 40	2 35	3 20	3 00	3 45	3 05	0 40	3 55	3 35	3 35	3 45	3 20	3 20	2 55	2 10	3 20	2 05	3 10	1 55	0 50	2 55	3 40	3 25	2 35	3 10	2 55	1 00	2 48	4 05	0 40
No. 34	3 10	3 30	3 30	4 00	3 30	3 40	3 45	3 50	3 45	4 45	4 15	1 30	3 45	3 45	4 35	3 00	3 10	3 20	3 30	3 40	3 20	2 30	3 45	3 00	0 40	3 10	3 00	3 20	3 00	4 15	1 10	0 40	3 14	4 45	0 40
No. 35	2 20	3 40	2 30	3 35	3 00	2 40	3 00	3 25	2 45	3 45	3 00	2 50	3 50	4 45	4 20	3 35	3 50	4 00	4 00	4 20	4 20	2 25	3 45	2 50	2 30	3 10	3 30	3 50	3 30	3 25	3 30	5 00	3 28	5 00	2 20
No. 36	3 15	4 45	3 15	4 00	4 05	3 10	3 35	3 25	3 05	4 25	3 55	3 45	4 15	3 50	3 40	3 25	2 00	3 05	3 00	2 35	3 35	2 35	3 35	2 45	2 05	3 00	4 40	3 40	3 30	4 25	1 30	4 00	3 24	4 45	1 30
No. 37	2 40	4 24	3 10	4 20	2 45	2 45	3 00	4 00	4 00	4 20	4 30	1 15	4 00	3 50	4 30	3 30	3 30	3 30	4 45	2 30	4 00	2 30	3 45	2 45	0 45	3 15	4 00	3 00	3 00	3 15	0 55	5 30	3 18	5 30	0 45
No. 38	2 45	3 45	2 45	4 45	3 00	3 30	3 00	4 00	3 15	4 00	2 45	0 25	3 30	3 00	3 15	3 15	3 15	2 30	3 30	2 00	3 15	2 00	3 15	2 00	0 45	3 15	3 00	0 45	3 00	3 00	0 30	2 00	2 47	4 00	0 25
No. 39	3 20	5 40	3 25	4 35	3 50	5 10	3 40	4 40	4 00	4 15	4 25	4 00	4 40	4 45	4 25	4 00	4 10	4 10	4 15	4 10	4 20	2 40	4 05	3 20	3 40	3 55	4 00	3 50	4 10	3 30	4 25	5 45	4 09	5 45	2 40
No. 40	3 38	4 19	3 00	4 30	4 35	2 50	3 52	4 07	4 00	4 20	3 00	0 17	4 12	4 30	3 45	3 30	3 40	3 45	4 20	2 45	4 05	4 05	4 15	3 20	0 12	4 15	2 43	0 35	3 20	3 00	0 35	0 30	3 14	4 35	0 12
Average time	2 59	4 14	3 05	4 17	3 32	3 15	3 28	3 49	3 36	4 20	3 41	1 52	4 02	4 02	4 13	3 35	3 34	3 46	4 02	3 10	3 56	2 48	3 47	2 56	1 23	3 43	3 34	2 50	3 17	3 30	1 45	3 08	3 23	....	....
High	3 [c]55	5 40	4 [c]45	5 [c]00	4 [c]45	5 10	5 [c]10	4 [c]40	4 [c]45	5 [c]50	5 [c]10	4 [c]15	5 [c]45	5 [c]25	6 [c]05	5 [c]30	4 [c]55	5 [c]30	5 [c]25	5 [c]00	4 [c]45	4 [c]30	4 [c]40	4 [c]25	3 [c]55	6 [c]05	4 40	4 [c]15	4 [c]50	4 [c]35	4 25	5 45	4 59	6 05	3 55
Low	1 55	3 10	1 55	3 35	2 45	1 40	2 35	2 50	2 45	3 45	2 45	0 07	3 00	3 00	3 15	3 00	2 00	2 30	2 55	2 00	3 10	2 00	3 10	1 55	0 12	2 55	2 45	0 35	2 20	2 35	0 25	0 30	2 17	3 45	0 07

Railroad Laboratories

No. 41	2 35	4 00	2 20	4 00	3 40	3 05	4 05	4 00	3 35	4 05	3 50	0 20	4 15	4 30	4 05	3 15	3 30	3 30	3 50	2 15	4 00	1 15	3 15	3 00	0 30	3 50	3 00	0 30	2 25	0 50	0 10	0 05	2 46	4 30	0 05

University and College Laboratories

No. 43	4 05	4 58	4 00	4 45	4 00	5 05	3 52	3 45	1 45	5 33	4 10	6 15	4 55	5 15	5 25	4 25	4 35	4 28	4 57	4 45	4 25	3 30	4 38	3 10	0 14	4 54	4 30	2 03	4 35	4 20	1 05	6 50	4 13	6 50	0 14
No. 44[b]	4 25	4 58	4 09	4 58	3 54	5 34	3 37	4 54	5 29	6 32	5 20	5 20	5 00	5 09	4 50	5 04	4 43	5 27	4 48	5 10	4 59	4 20	4 23	4 19	5 34	6 33	5 28	5 14	5 23	5 12	4 57	4 27	5 00	6 33	3 37
No. 45	3 08	3 56	3 26	5 51	4 43	3 17	5 33	5 07	4 43	6 23	5 30	1 06	5 31	5 24	6 54	5 11	5 14	4 38	3 52	1 53	4 15	1 07	3 52	2 28	0 05	4 15	3 50	2 27	2 38	1 42	0 33	0 45	3 44	6 54	0 05
No. 47	3 00	4 50	3 00	4 40	4 05	3 45	3 10	4 05	2 45	3 05	3 20	2 30	3 50	3 00	2 55	2 50	3 50	3 00	3 40	1 50	3 15	1 25	3 10	2 05	1 40	1 50	3 50	2 15	2 25	3 20	1 15	4 00	3 03	4 50	1 15
No. 48	2 30	4 30	2 45	4 40	2 45	4 40	3 00	3 10	3 05	3 05	4 10	3 10	3 30	3 20	4 10	3 30	3 50	3 50	5 20	3 15	3 45	4 10	3 25	2 10	2 45	3 30	2 30	3 10	2 40	2 40	0 40	3 00	3 20	5 20	0 40
No. 49	2 36	3 20	2 01	2 37	2 21	2 37	2 06	3 02	2 38	3 18	3 22	3 40	3 13	3 03	2 45	1 52	2 10	2 32	2 15	2 01	3 42	3 07	3 25	1 37	2 32	2 28	3 00	4 00	4 15	2 40	3 05	3 35	2 17	4 15	1 37
No. 51	3 17	4 34	3 30	3 57	3 13	3 30	3 03	3 09	2 49	4 05	3 19	3 51	3 36	4 13	4 30	3 57	4 24	3 52	4 21	3 04	4 17	4 20	4 49	2 39	3 09	2 34	4 39	3 56	3 25	5 31	2 32	5 21	3 48	5 31	2 32
No. 52	3 30	6 20	3 10	5 10	4 20	3 40	3 40	4 30	3 40	4 10	5 30	0 32	4 30	3 30	4 20	5 20	5 10	3 50	5 30	3 40	4 30	0 52	5 30	4 00	2 20	5 30	5 10	4 30	3 50	4 00	0 27	4 00	3 54	6 20	0 27
Average time	3 11	4 41	3 15	4 34	3 41	4 01	3 30	3 57	3 22	4 32	4 20	3 17	4 16	4 07	4 29	3 52	4 15	3 57	4 19	3 12	4 08	2 51	4 09	2 49	2 17	2 17	4 08	3 27	3 39	3 40	1 49	3 59	3 40	....	....
High	4 [c]25	6 20	4 [c]09	5 51	4 43	5 [c]34	5 33	5 07	5 [c]29	6 [c]32	5 30	6 15	5 31	5 24	6 54	5 20	5 14	5 [c]27	5 30	5 [c]10	4 [c]59	4 [c]20	5 30	4 [c]19	5 [c]34	6 [c]33	5 [c]28	5 [c]14	5 [c]23	5 31	4 [c]51	6 50	5 27	6 54	4 10
Low	2 30	3 20	2 01	2 31	2 21	2 37	2 06	3 02	1 45	3 05	3 19	0 32	3 13	3 00	2 45	1 52	2 10	2 32	2 15	1 50	3 15	0 52	3 10	1 37	0 05	1 50	2 30	2 03	2 25	1 42	0 27	0 45	2 12	3 20	0 05
Grand average Value	3 04	4 38	3 07	4 20	3 37	3 49	3 35	4 10	3 41	4 22	4 02	2 47	4 00	4 20	4 19	3 45	3 51	3 55	4 15	3 24	3 58	2 50	4 00	3 07	1 54	3 58	3 51	3 18	3 25	3 42	2 07	3 54	3 37	....	....
Grand High	4 25	7 00	4 45	5 51	5 15	7 05	5 33	6 20	6 00	6 32	5 42	6 15	5 45	6 35	6 54	6 08	5 14	5 35	5 30	5 45	5 40	4 55	5 55	4 35	5 34	6 33	5 28	8 05	5 25	5 50	5 30	6 50	5 54	7 05	4 25
Grand Low	1 55	3 00	1 20	2 20	2 21	1 40	2 06	2 50	1 45	0 45	2 45	0 07	2 55	3 00	2 45	1 52	2 00	2 30	2 15	1 50	2 20	0 52	2 00	1 37	0 05	1 50	1 45	0 30	1 40	0 50	0 10	0 05	1 44	3 00	0 05
Difference	2 70	4 00	3 25	3 31	2 94	5 65	3 27	3 70	4 55	5 87	2 95	6 08	2 90	3 35	4 09	4 58	3 14	8 05	3 15	3 95	3 20	4 03	3 55	2 98	5 29	4 83	3 83	7 75	3 85	5 00	5 20	6 45	4 10	7 75	2 70

[a] Tests not made. [b] Gillmore needle used. [c] Tests not reported.

TABLE II.—FINAL TIMES OF SETTING OF CEMENTS.

Tests made in accordance with the A.S.T.M. Standard Specification and Tests for Portland Cements (Serial Designation C 9 - 26).
Vicat needle used unless otherwise indicated.

Laboratory	Final Time of Setting, Cements 1-32																																Average Value	High Value	Low Value
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32			
	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
COMMERCIAL TESTING LABORATORIES																																			
No. 1	5 45	8 10	6 05	8 35	6 30	7 20	7 50	7 10	6 50	6 20	7 35	6 40	6 25	7 20	6 30	6 45	7 30	7 15	8 30	7 55	6 50	6 50	8 45	6 55	6 20	7 55	7 20	6 45	6 50	5 40	6 10	6 45	6 58	8 45	5 40
No 3	6 10	8 10	5 40	7 00	5 45	.....	6 20	8 30	6 15	8 00	7 05	7 45	6 40	7 10	5 45	5 55	5 25	6 35	7 20	7 55	7 50	6 45	7 20	5 05	5 35	8 30	7 05	.....	7 30	7 45	8 30	8 40	7 00	8 40	5 05
No. 4	4 30	6 35	4 25	5 55	5 10	4 15	5 30	5 40	5 10	5 50	5 20	3 30	5 20	5 30	5 45	4 45	5 05	5 25	6 30	4 30	5 05	5 10	4 35	4 00	4 00	6 15	6 20	5 15	4 30	5 00	4 20	5 10	5 08	6 35	3 30
No. 5[a]	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	....
No. 6	5 35	9 00	4 55	7 45	5 46	7 00	5 50	6 50	5 48	6 47	6 16	6 00	6 50	7 20	6 30	7 10	5 20	7 45	7 50	7 00	7 15	6 40	6 25	5 55	5 30	7 55	7 00	6 25	6 20	6 15	4 10	8 05	6 36	9 00	4 10
No. 7	5 45	8 05	5 15	6 10	5 25	5 55	5 35	7 15	7 50	8 55	8 05	7 40	6 40	5 20	6 20	6 00	6 20	7 10	7 40	6 25	6 30	4 35	6 00	5 50	5 45	6 15	6 00	5 45	6 15	6 25	6 10	6 25	6 26	8 05	4 35
Average time	5 33	8 00	5 16	7 05	5 43	6 07	6 13	7 05	6 23	7 10	6 52	6 19	6 23	6 32	6 10	6 07	5 56	6 50	7 34	6 46	6 42	6 00	6 37	5 33	5 26	7 22	6 45	6 02	6 17	6 13	5 52	7 01	6 26	.....	....
High	6 10	9 00	6 05	8 35	6 30	7 20	7 50	8 30	7 50	8 55	8 05	7 45	6 50	7 20	6 30	7 10	7 30	7 45	8 30	7 55	7 50	6 50	8 45	6 55	6 20	8 30	7 20	6 45	7 30	7 45	8 30	8 40	7 37	.....	....
Low	4 30	6 35	4 25	5 55	5 10	4 15	5 30	5 40	5 10	5 50	5 20	3 30	5 20	5 20	5 45	4 45	5 05	5 25	6 30	4 30	5 05	4 35	4 35	4 00	4 00	6 15	6 00	5 15	4 30	5 00	4 10	5 10	5 06	.....	....
GOVERNMENT, STATE AND MUNICIPAL LABORATORIES																																			
No. 9	4 05	7 05	4 40	6 40	5 05	6 20	4 40	5 20	4 55	6 45	4 55	5 45	4 35	5 25	5 30	4 35	4 45	5 05	5 25	4 00	4 25	4 20	6 25	4 15	4 35	6 50	6 30	5 25	5 00	6 35	5 50	7 35	5 25	7 35	4 05
No. 10	4 15	6 40	4 45	6 00	5 00	5 30	7 00	7 30	5 30	6 45	6 10	5 40	5 20	6 45	6 50	5 30	6 20	7 00	7 00	6 00	6 05	5 20	6 40	5 30	4 20	6 50	6 10	6 00	5 25	6 00	6 20	7 00	6 02	7 30	4 15
No. 11	6 30	7 00	5 00	7 00	6 45	6 00	6 00	6 45	5 45	7 15	6 30	5 30	5 15	6 45	5 00	5 30	5 45	6 45	7 00	5 30	6 15	5 30	6 30	5 45	5 30	6 30	6 15	6 15	5 15	6 45	4 45	4 45	6 03	7 15	4 40
No. 12	8 30	12 30	8 45	.....	8 05	8 55	7 10	10 20	11 05	11 25	11 15	9 35	9 35	9 45	11 25	8 35	9 20	9 55	9 30	9 55	10 00	9 05	10 30	7 25	9 05	9 50	8 15	8 25	8 40	7 30	10 00	9 35	9 28	12 30	7 10
No. 13	4 00	6 50	3 30	5 00	4 15	6 15	5 30	7 40	6 05	6 20	7 10	6 50	6 35	6 40	6 10	5 30	4 50	5 40	5 50	6 10	5 35	6 35	5 50	5 00	5 50	6 25	4 45	5 15	5 40	5 45	5 20	5 05	5 45	7 40	3 30
No. 14[b]	5 00	6 30	6 30	6 30	6 30	7 00	5 45	7 15	6 15	7 15	5 45	6 00	5 30	7 00	6 15	5 30	5 45	6 00	5 45	7 30	6 15	.....	6 15	5 00	7 15	7 30	6 30	5 30	6 45	7 15	7 30	8 30	6 26	8 30	5 00
No. 15	5 10	7 20	4 55	6 50	5 25	5 15	5 30	6 05	5 55	5 50	5 35	6 25	6 40	6 00	6 40	5 20	5 30	6 10	6 40	5 25	5 20	5 00	6 10	4 50	5 00	6 35	6 05	5 45	4 55	5 15	4 20	6 50	5 45	7 20	4 25
No. 16	4 45	.....	6 15	.....	6 30	.....	5 45	7 00	6 45	.....	.....	.....	7 15	7 15	6 45	7 15	6 45	.....	.....	7 00	.....	.....	6 00	5 45	6 15	6 45	6 30	7 00	6 45	6 45	7 00	6 00	6 33	7 15	4 40
No. 17	5 30	7 00	6 00	6 30	5 35	6 10	6 20	6 35	7 35	7 40	6 55	6 15	7 00	7 10	8 00	6 10	6 20	6 10	6 30	6 00	6 00	5 00	6 00	4 50	4 40	8 00	6 00	5 20	5 45	6 35	5 30	6 00	6 17	8 00	4 40
No. 18[a]	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	....
No. 19	4 25	6 25	4 35	6 00	4 25	3 45	3 45	4 45	4 35	5 15	4 35	5 20	5 45	5 35	5 20	5 35	5 30	5 40	6 35	4 50	5 25	4 55	6 20	4 35	5 30	7 00	6 15	5 40	6 05	6 25	4 50	7 15	5 24	7 15	3 45
No. 20	4 55	7 23	6 13	7 03	6 45	7 03	6 15	5 50	6 50	7 10	7 12	6 08	6 00	8 05	7 27	7 23	5 39	6 47	7 02	6 47	6 25	4 25	6 15	5 30	5 07	6 27	5 57	6 07	5 47	5 57	4 20	7 50	6 23	8 05	4 20
No. 21	4 36	6 27	4 38	6 10	5 13	7 11	6 29	7 16	6 21	6 40	6 33	5 26	6 15	6 40	6 58	6 03	6 21	6 53	7 40	6 06	6 24	5 28	6 17	5 40	4 15	5 41	7 00	5 13	4 44	7 05	4 29	6 54	6 06	7 40	4 15
No. 22	5 10	8 15	5 25	7 30	5 20	5 55	4 35	7 00	6 15	7 05	7 30	6 40	6 00	7 35	8 05	5 45	6 00	6 20	7 45	6 10	7 45	5 55	7 40	4 45	5 25	7 25	5 55	5 20	5 20	7 10	5 35	7 30	6 27	8 15	4 35
No. 23	4 30	6 30	4 35	5 45	6 30	5 00	5 25	6 30	5 50	7 00	6 40	4 40	6 45	6 40	7 00	6 35	6 25	5 45	6 20	5 55	6 10	5 00	7 00	5 00	5 00	7 00	6 10	4 25	4 55	5 25	3 35	6 05	5 49	7 00	3 35
No. 24	6 10	9 25	5 40	7 50	6 10	8 45	6 30	7 15	7 20	9 00	8 50	8 00	8 10	8 15	7 15	7 00	7 05	7 25	9 40	9 25	8 10	6 30	8 35	6 10	8 00	10 00	7 05	9 30	9 20	7 25	8 40	9 50	7 57	10 00	5 40
No. 25	4 15	5 50	4 50	6 13	5 05	5 18	6 55	7 20	6 15	6 48	6 20	5 50	5 35	6 40	6 48	5 23	5 55	6 00	5 25	5 40	5 55	4 45	5 45	4 50	4 40	5 10	5 15	4 45	5 05	8 30	5 25	6 15	5 45	8 30	4 15
No. 26	4 30	9 00	4 15	7 15	5 30	7 45	6 00	7 00	5 15	7 30	6 15	6 30	5 30	6 45	6 30	5 30	6 30	6 00	6 00	5 30	5 30	5 00	5 30	5 00	5 00	6 30	5 45	5 30	5 00	7 30	5 30	7 00	6 03	9 00	4 15
No. 27	3 55	5 45	4 00	5 20	4 00	4 10	4 00	4 20	4 30	5 30	5 15	4 10	4 35	5 00	4 50	4 00	4 25	5 00	5 20	4 30	5 25	4 30	5 10	3 40	4 50	5 15	3 55	4 25	5 00	5 15	5 50	3 55	4 41	5 50	3 40
Average time	5 01	7 24	5 15	6 29	5 44	6 15	5 45	6 46	6 17	7 08	6 40	6 10	6 14	6 53	6 50	5 58	6 04	6 23	6 47	6 15	6 18	5 27	6 36	5 12	5 34	6 59	6 08	5 53	5 52	6 37	6 06	6 53	6 14	.....	....
High	8 30	12 30	8 45	7 50	8 05	8 55	7 10	10 20	11 05	11 25	11 15	9 35	9 35	9 45	11 25	8 35	9 20	9 55	9 40	9 55	10 00	9 05	10 30	7 25	9 05	10 00	8 15	9 30	9 20	8 30	10 00	9 55	9 32	.....	....
Low	3 55	5 45	3 30	5 00	4 00	3 45	3 45	4 20	4 30	5 15	4 35	4 10	4 35	5 00	4 50	4 00	4 25	5 00	5 20	4 00	4 25	4 20	5 10	4 15	4 15	5 10	3 55	4 25	4 45	5 15	3 35	3 55	4 28	.....	....

PORTLAND CEMENT MANUFACTURERS' LABORATORIES

No. 28	4 35	7 00	5 10	6 45	4 55	5 10	4 45	5 45	6 00	6 25	5 50	6 00	5 45	6 00	6 30	5 00	5 35	5 55	6 10	6 00	6 50	5 35	5 40	4 45	5 20	7 25	5 15	4 25	5 25	5 05	5 00	7 25	**5 43**	**7 25**	**4 25**
No. 29	5 30	5 20	5 40	7 10	5 10	5 00	6 35	5 25	6 00	6 40	6 25	4 15	7 10	7 00	7 10	5 20	7 00	7 25	7 45	6 00	7 30	4 50	7 10	6 00	4 05	6 45	6 50	4 50	5 20	7 00	5 30	5 45	**6 11**	**7 45**	**4 05**
No. 30^{b}	7 05	9 00	7 50	8 05	7 50	7 45	8 20	7 55	8 05	8 30	8 10	7 30	8 40	8 20	8 50	8 25	8 00	8 10	8 15	8 30	8 10	7 50	8 10	7 45	7 55	9 05	8 05	7 55	8 10	8 00	7 45	8 15	**8 07**	**9 05**	**7 05**
No. 31	5 20	7 30	4 40	6 45	5 30	5 30	5 00	6 15	6 30	7 40	6 30	6 00	6 15	6 30	7 00	6 15	6 30	7 00	7 15	6 05	6 05	6 10	6 40	5 20	6 00	7 30	6 10	6 00	4 30	5 30	4 10	6 00	**6 08**	**7 40**	**4 10**
No. 32^{a}	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	....
No. 33	3 50	5 45	3 40	6 25	5 15	3 15	4 10	5 50	5 10	6 10	5 15	2 05	6 25	6 15	6 50	6 25	6 35	6 25	5 55	4 35	6 00	4 15	5 40	3 25	2 55	4 30	6 25	5 55	5 20	5 45	5 05	3 55	**5 10**	**6 50**	**2 05**
No. 34	5 40	7 30	6 00	7 00	6 20	6 20	5 30	6 15	7 00	8 00	7 45	5 40	6 30	6 20	6 50	5 15	6 00	5 50	6 05	6 25	6 10	5 05	5 30	5 20	3 25	7 30	6 30	6 15	7 00	8 00	4 15	3 30	**6 08**	**8 00**	**3 25**
No. 35	5 25	8 40	5 20	7 55	6 40	6 45	5 50	7 40	6 00	7 00	6 20	7 20	7 40	8 00	7 30	6 50	6 50	7 20	7 15	7 40	8 00	5 35	6 20	6 00	5 20	5 50	6 05	6 40	5 40	6 40	6 00	8 15	**6 46**	**8 40**	**5 20**
No. 36	5 30	6 45	5 00	6 00	5 40	4 50	5 10	6 05	4 30	6 25	5 35	5 35	6 10	5 10	4 45	4 50	5 00	4 15	4 45	5 35	5 40	4 10	5 20	4 05	5 00	6 05	5 40	5 00	4 45	5 45	4 00	5 55	**5 18**	**6 45**	**4 00**
No. 37	4 30	8 30	6 00	9 00	5 30	5 30	6 00	7 30	7 25	7 00	7 20	4 30	7 00	7 30	8 00	7 00	6 30	6 45	9 00	5 00	7 20	5 00	6 20	5 25	4 45	6 30	8 00	5 50	5 45	5 35	4 05	9 30	**6 24**	**9 30**	**4 05**
No. 38	4 15	6 00	4 30	5 45	5 00	5 15	5 00	6 00	5 30	5 45	5 00	4 30	5 30	5 30	5 15	5 00	5 30	5 00	6 00	5 00	5 45	5 00	5 15	4 15	3 45	6 30	6 15	5 00	5 00	5 00	4 00	5 45	**5 13**	**6 30**	**4 00**
No. 39	6 15	10 15	6 35	8 55	6 40	8 15	6 50	8 25	7 50	8 10	8 30	8 00	8 25	8 05	8 00	7 20	7 00	8 15	8 10	8 30	8 20	6 10	7 40	6 00	7 20	8 00	7 00	6 45	7 40	6 45	8 05	9 00	**7 43**	**10 15**	**6 00**
No. 40	6 38	7 26	5 40	7 35	6 30	5 35	6 07	6 30	6 30	8 00	6 00	4 00	7 07	6 15	6 15	5 30	6 00	6 00	6 00	4 35	6 10	6 10	6 10	5 00	5 20	7 00	6 28	3 45	5 25	5 50	4 45	4 32	**5 46**	**8 00**	**3 45**
Average time	5 13	7 28	5 30	7 17	5 55	5 46	5 46	6 38	6 22	7 09	6 33	5 27	6 53	6 45	6 55	6 06	6 22	6 32	6 53	6 10	6 50	5 29	6 20	5 17	5 07	6 48	6 34	5 42	5 50	6 15	5 13	6 29	**6 13**	.....	....
High	7^{b}05	10 15	7^{b}50	9 00	7^{b}50	8 15	8^{b}20	8 25	8^{b}05	8^{b}30	8 30	8 00	8^{b}40	8^{b}20	8^{b}50	8 25	8^{b}00	8 15	9 00	8^{b}30	8 20	7^{b}50	8^{b}10	7^{b}45	6 00	9^{b}05	8^{b}05	7^{b}55	8^{b}10	8^{b}00	8 05	9 30	**8 17**	.....	....
Low	3 50	5 20	3 40	5 45	4 55	3 15	4 10	5 25	4 30	5 45	5 00	2 05	5 30	5 10	4 45	5 00	5 00	4 15	4 45	4 35	5 40	4 10	5 15	3 25	2 55	4 30	5 40	3 45	4 30	5 00	4 00	3 30	**4 32**	.....	....

RAILROAD LABORATORIES

No. 41	**3 35**	**6 00**	**3 50**	**5 00**	**7 20**	**5 05**	**6 20**	**5 40**	**5 10**	**6 30**	**6 20**	**3 45**	**5 45**	**6 40**	**6 05**	**4 15**	**5 30**	**5 35**	**5 30**	**4 45**	**5 30**	**4 30**	**6 00**	**5 00**	**4 00**	**6 30**	**6 00**	**4 30**	**4 30**	**3 50**	**4 30**	**4 00**	**5 14**	**7 20**	**3 35**

UNIVERSITY AND COLLEGE LABORATORIES

No. 43	6 05	8 50	6 15	7 10	6 15	7 10	7 05	6 35	5 55	7 53	6 55	7 35	8 00	7 35	8 35	6 55	7 20	6 20	7 17	8 15	7 00	8 15	7 00	5 00	7 10	7 39	7 15	7 03	7 05	6 35	7 35	9 10	**7 12**	**9 10**	**5 00**
No. 44^{b}	8 00	10 28	8 06	10 26	9 35	10 28	8 06	10 16	9 35	11 32	9 29	9 25	10 00	10 03	9 18	9 21	8 09	10 24	9 21	11 12	11 20	10 47	9 24	9 08	9 31	14 21	9 26	9 20	8 33	8 42	7 58	8 35	**9 43**	**14 21**	**7 58**
No. 45	8 06	9 33	8 05	9 37	7 56	8 30	9 18	9 53	8 14	9 55	9 54	7 26	9 22	9 04	10 00	5 57	8 57	7 42	7 49	8 42	8 40	8 05	6 15	5 48	7 21	6 42	8 53	8 07	6 00	8 10	5 20	8 15	**8 10**	**10 00**	**5 20**
No. 47	5 15	7 35	5 00	7 40	6 35	6 15	6 10	7 05	4 55	6 05	5 35	4 55	6 05	5 45	5 35	4 50	5 50	6 15	6 25	5 05	6 45	4 55	6 25	4 35	5 25	7 35	6 25	5 00	5 10	6 50	5 00	7 30	**5 57**	**7 40**	**4 35**
No. 48	4 30	6 15	4 15	5 55	4 15	5 40	4 20	4 40	5 05	4 50	5 40	4 40	5 15	6 05	5 10	5 00	4 50	5 35	6 35	5 00	5 15	5 40	5 55	3 55	4 00	5 30	4 00	3 55	4 10	4 10	3 55	4 45	**4 57**	**6 35**	**3 55**
No. 49	4 47	5 20	3 17	5 11	4 15	4 53	4 24	5 34	4 06	6 21	5 49	5 29	5 10	5 26	4 46	3 47	3 32	4 48	4 48	5 04	5 54	5 22	5 13	3 10	5 20	5 36	5 18	5 43	6 07	4 50	6 55	5 45	**5 04**	**6 55**	**3 10**
No. 51	6 17	9 00	7 25	8 31	6 13	8 34	6 23	8 48	6 53	8 37	8 12	8 26	8 18	8 26	7 06	7 01	7 57	8 13	7 38	7 52	10 42	10 35	10 29	5 39	7 19	9 44	7 29	7 21	8 45	9 41	9 07	9 31	**8 12**	**10 42**	**5 39**
No. 52	5 00	9 30	6 00	8 30	7 00	7 00	6 30	8 00	7 00	8 00	8 00	5 30	6 30	6 00	7 00	7 30	7 30	7 00	9 00	6 00	8 35	5 00	8 30	6 00	6 30	10 00	8 00	6 30	7 00	8 00	4 50	9 00	**7 18**	**10 00**	**4 50**
Average time	5 59	8 19	6 02	7 52	6 30	7 19	6 32	7 37	6 28	7 54	8 01	6 41	7 20	7 56	7 11	6 17	6 46	7 02	7 22	7 08	8 01	7 19	7 24	5 25	6 34	8 23	7 06	6 38	6 36	7 07	6 20	7 49	**7 04**	.....	....
High	8 06	10^{b}28	8^{b}06	10^{b}26	9^{b}35	10^{b}28	9 18	10^{b}16	9^{b}35	11^{b}32	9 54	9^{b}25	10^{b}00	10^{b}03	10 00	9^{b}21	8 57	10^{b}24	9^{b}21	11^{b}12	11^{b}20	10^{b}47	10 29	9^{b}08	9^{b}31	14^{b}21	9^{b}26	9^{b}20	8 45	9 41	9 07	9 31	**9 55**	.....	....
Low	4 30	5 20	3 17	5 11	4 15	4 53	4 20	4 40	4 06	4 50	5 35	4 40	5 10	5 26	4 46	4 50	3 32	4 48	4 48	5 00	5 15	4 55	5 13	3 10	4 00	5 30	4 00	3 55	4 10	4 10	3 55	4 45	**4 35**	.....	....
Grand Average Value	5 16	7 38	5 27	7 00	5 58	6 17	5 58	6 54	6 20	7 16	6 54	6 01	6 37	7 00	6 49	6 02	6 15	6 35	6 59	6 25	6 48	5 52	6 40	5 18	5 35	7 13	6 30	5 57	6 00	6 30	5 50	6 54	**6 23**	.....	....
Grand High	8 30	12 30	8 45	10^{b}25	9^{b}35	10^{b}28	9 18	10 20	11 05	11^{b}32	11 15	9 35	10^{b}00	10^{b}03	11 25	9^{b}21	9 20	10^{b}24	9 40	11^{b}12	11^{b}20	10^{b}47	10 30	9^{b}08	9^{b}31	14^{b}20	9^{b}26	9 30	9 20	9 41	10 00	9 50	**10 15**	.....	....
Grand Low	3 35	5 20	3 15	5 00	4 00	3 15	3 45	4 20	4 05	4 50	4 35	2 05	4 35	5 00	4 45	3 47	3 32	4 15	4 45	4 00	4 25	4 10	4 35	3 10	3 25	4 30	3 55	3 45	4 10	3 50	3 35	3 30	**4 03**	.....	....
Difference	4 55	7 10	5 30	5 25	5 35	7 13	5 33	6 00	7 00	6 42	6 40	7 30	5 25	5 03	6 40	5 34	5 48	6 09	4 55	7 12	6 55	6 37	5 55	5 58	6 06	9 51	5 31	5 45	5 10	5 51	6 25	6 20	**6 12**	.....	....

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[a] Tests not made. [b] These laboratories used the Gillmore needle.

When laboratories using supposedly the same methods get such a wide variation in results, it is quite apparent that either the methods followed were faulty or the conditions governing the tests were not well controlled.

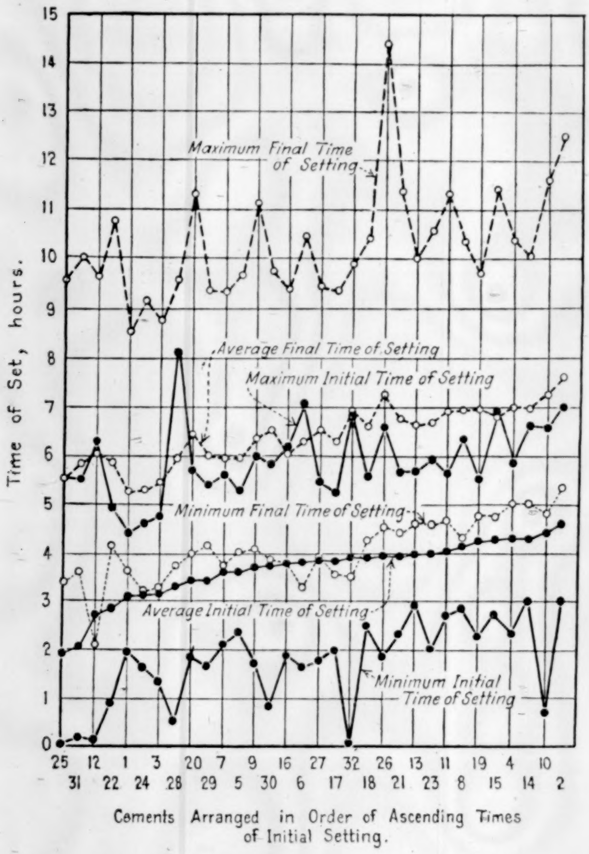

FIG. 1.—Comparison of Times of Setting of 32 Cements.

Probably the most important factors affecting the time of setting of cement are:

1. Normal consistency of paste,
2. Humidity of curing chamber,
3. Temperature of curing chamber,
4. Humidity and temperature of room in which tests are made,
5. Temperature of mixing water,
6. Condition of test apparatus.

When it is considered that the different laboratories reported a range for one cement of from 19.5 to 26 per cent in the amount of water required for normal consistency, it is not surprising that the time of setting varied greatly. A study of the time of setting results from those laboratories which reported the high and low values of normal consistency for the different cements showed that the initial times of setting were generally higher in the case of the laboratories reporting high normal consistencies, but the effect of differences in normal consistency on the final times of setting was not so marked.

The generally relatively small variations in setting times obtained with the extremes in the normal consistency found for an individual cement would indicate that the variations in setting times reported are more likely caused by the personal equation of the operator and other conditions surrounding the tests in a given laboratory rather than by differences in normal consistency although this factor undoubtedly exerted some influence on the initial time of set. The data on the other factors affecting time of setting are not complete enough to permit the drawing of definite conclusions.

Penetration Tests:

The present system of making time of setting tests results in a great waste of time as it is often necessary to make many trials before the exact penetration is obtained. This inefficiency coupled with such unsatisfactory results as just pointed out makes it particularly timely that the possibilities of a new test be examined. Some studies have been made on a so-called penetration test using present standard equipment and certain modifications. These penetration tests were made on cement pastes of normal consistency and paste of a fluid consistency mixed with 42 per cent of water by weight of cement. The standard Vicat needle weighing 300 g. and a modified Vicat needle weighing 100 g. were used.

A comparison between the penetration on the fluid cement mixtures and the paste of normal consistency indicates that the latter would probably be the most satisfactory so far as the application of the needle test itself is concerned. The reason for this is the great length of time that elapsed between the adding of the water and the stiffening of the paste to the point where no penetration took place; also it does not appear from the data that any greater accuracy would result from selecting a later period using the fluid paste

In fixing a criterion by which the suitability of a cement as to its time of setting is to be measured, the obvious solution seems to lie in the selection of a time limit within which a penetration less than the full depth must not take place. It seems that the full penetration of the standard Vicat needle at 1 hour would be a suitable period for making the test.

So far as initial setting is concerned, this limit and this method would seem to offer possibilities. Results obtained with the modified Vicat needle were more erratic than those of the standard needle, and as the use of this lighter needle did not develop any advantages over the standard, it would appear that further investigations along this line may be confined to the use of the standard apparatus.

Final decision as to the exact time limit which must be put on the degree of penetration cannot be made until a more comprehensive series of tests has been carried out by several laboratories. Sub-Committee VI has tests under way to secure further information on this point and to correlate the results of time of setting tests with the behavior of the cements when made into concrete under normal field conditions. The field comparison is especially important in view of the fact that it is difficult to obtain concordant results by the method now considered "standard." In these tests particular attention will be given to "marginal" cements, that is, cements which set in about 1 hour.

Respectfully submitted on behalf of the sub-committee,

F. W. KELLEY,
Chairman.

REPORT OF SUB-COMMITTEE VII ON STRENGTH: REPORT ON "COOPERATIVE TESTS OF THIRTY-TWO PORTLAND CEMENTS BY FORTY-SEVEN LABORATORIES"

INTRODUCTION

In recent years Committee C-1 has given considerable attention to the A.S.T.M. methods of testing portland cement and many tests have been made in a study of the factors affecting strength and the uniformity of test results obtained under different conditions.

In 1924 and 1925, this sub-committee carried out an investigation in which such factors as form of specimen, mixture, consistency, method of molding, age at test, etc., were studied. The tests were made for the most part on standard sand mortars; a few tests on neat cement briquets were included. The tests were carried out on the same cement by about 20 laboratories. In 1925, Committee C-1 prepared a Manual of Cement Testing, which supplemented the A.S.T.M. Standard Specifications and Tests for Portland Cement (C 9 – 21), in order to aid in securing greater uniformity in cement tests by different laboratories. Some of the methods of testing incorporated in the Manual have since been made a part of the present Standard Specifications and Tests for Portland Cement (C 9 – 26).[1]

In continuing its study of cement testing, the committee early in 1925 began to direct its attention to the possibilities of tests on neat cement pastes for determining the strength properties of cement, and since that time a considerable amount of research work has been carried out on fluid cement-water mixtures by laboratories working both independently and in cooperation with this sub-committee. The following reports on tests relating to this subject have been presented to Committee C-1 or have come to its attention:

1. *October 23, 1924.* "New Studies in the Properties of Portland Cement," by Thaddeus Merriman, *Engineering News-Record*, Vol. 93, p. 669. Data on neat briquets mixed with 43 per cent of water by weight, cement grout poured into briquet molds in order to eliminate variations in tests due to personal equation of operator in molding specimens.
2. *July 31, 1925.* A Brief Report on Compression Tests of Neat Portland Cement as Criterion of Concrete Strength, by Duff A. Abrams. Summary of tests made from 1917 to 1925 in Series 83, 104, 105, 124, 165, 185 and J63 at the Structural Materials Research Laboratory, Lewis Institute, Chicago.

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 23.

3. *November 10, 1925.* Progress Report of the Special Committee on Cement, Am. Soc. Civil Engrs., Thaddeus Merriman, chairman. Discusses methods of testing cement in neat and 1:2 standard sand mixtures. Gives data on tensile strength of neat cements mixed with 43 per cent water by weight.

4. *May 1, 1926.* "Fluid Cement-Water Mixtures as a Criterion of Concrete Strength," by Duff A. Abrams (Series 205), Structural Materials Research Laboratory, Lewis Institute, Chicago. An extensive investigation which included the following:

KIND OF TEST	NUMBER
Compression tests of neat cement	7750
Compression and tension tests of mortar, and tension tests of neat cement	2135
Compression tests of concrete	1575
Flow tests of neat cement	3840

5. *September 18, 1926.* "Tests of Fluid Cement-Water Mixtures," by Duff A. Abrams. Compression tests of fluid cement-water mixtures and compression and tension tests of 1:3 standard sand mortar from the same cement by 12 laboratories.

The foregoing reports presented and discussed data relating to the underlying principles and to studies of different mixtures and forms of specimen for strength tests of fluid cement-water mixtures. The early data and the experience of members of the committee indicated that compression tests of 2-in. cubes of neat cement mixed with about 42 per cent of water by weight were the most promising. A study of the uniformity of compression tests of fluid cement-water mixtures and of compression and tension tests of 1:3 standard sand mortar made by 12 laboratories using the same cement were presented in the report of September 18, 1926, and it was pointed out that before it would be practicable to use tests of fluid cement-water mixtures as a basis for specifications for portland cement, it would be necessary to make, first, tests on a large number of different portland cements by different operators in order to establish proper strength requirements, and second, studies of time of setting and soundness of portland cement using fluid cement-water mixtures. Another important feature to be studied was the possibility of developing an acceptance test for cement which could be made at an earlier period than the present 7 and 28-day tests.

Tentative plans were made for carrying out these tests at a meeting of this sub-committee held in New York City on September 27, 1926. The outline of the tests was completed through subsequent correspondence and arrangements were made with 52 laboratories to carry out the tests on 32 portland cements. The complete outline was submitted with the first progress report to Committee C-1 on January 18, 1927. A condensed outline appears in Table I of this report.

TABLE I.—OUTLINE OF COOPERATIVE CEMENT TESTS.

1:3 Standard Sand Mortar Tests

Mix 750 g. of standard sand and 250 g. of cement in a batch.

Water for mortar based on the normal consistency of the cement.

Mortar mixed by the standard method of kneading with the hands.

Make 3 briquets from a batch.

Briquets molded by thumbing 12 times on each side, using a pressure of between 15 and 20 lb.

Fluid Cement-Water Mixture Tests

Cement: 32 different portland cements purchased in the open market.

Use 1400 g. cement and 588 cc. of water for a batch.

Place cement and water in an 8-in. metal stew pan and allow 1 minute for absorption of water and then mix paste vigorously with an 11-in. metal spoon for 1 minute.

Immediately after mixing, mold three 2-in. cubes (or three 2 by 4-in. cylinders) and three briquets from each batch, stirring the paste during filling. Fill each mold in a set half full and repeat the operation filling each mold to overflowing.

Concrete Tests

Mix 5 lb. cement, 12 lb. dry sand, 18 lb. dry gravel or crushed stone and 3 lb. water for a batch; this will give sufficient concrete for one 6 by 12-in. cylinder.

Mix concrete in a shallow metal pan with a blunted 10-in. bricklayer's trowel; mix cement and fine aggregate dry, add coarse aggregate and mix dry. Add water and mix mass until homogeneous in appearance.

Immediately after mixing, make flow test and after flow test, remix concrete and place in cylinder mold in 3 layers, rodding each layer 25 times with a ⅝-in. bullet-pointed steel rod.

Mix by Weight	Consistency	Specimen	Age at Test	Remarks	Strength Tests		Report Tests on Form
					On Each Cement	On 32 Cements	
				STRENGTH TESTS			
1:3 (Standard Sand)	Normal	Briquets	3 days 7 days 28 days 3 months	Mix 4 batches for a given cement on same day and make 3 briquets from each batch for test at a given age.	12	384	A
Neat Cement	42 per cent water by weight of cement	2-in. cubes or 2 by 4-in. cylinders, briquets	3 days 7 days 28 days 3 months	Mix 4 batches for a given cement on same day. Make three 2-in. cubes (or 2 by 4-in. cylinders) and three briquets from each batch for test at a given age.	24	384 cubes (or cylinders) 384 briquets	B
1:2.4:3.6 (Concrete)	Water-ratio 0.90	6 by 12-in. cylinder	7 days 28 days	For a given cement, mix 2 batches concrete on each of 3 different days, each day making 1 cylinder for test at 7 days and 1 for test at 28 days.	6	192	E
					Total...	1344	

MISCELLANEOUS TESTS

Cement	Aggregate	Report Tests on Form
Normal consistency Time of setting (Vicat) Soundness Fineness	Sieve analysis Absorption after ½, 1, 2, 6 and 24 hours Unit weight (fine, coarse and mixed aggregate) Specific gravity Silt Organic impurities	C D and F

PURPOSE AND SCOPE OF PRESENT INVESTIGATION

The purpose of this investigation was to obtain:

1. A comparison of the uniformity of compression tests of 2-in. neat cement cubes (or 2 by 4-in. cylinders) and tension tests of neat cement briquets mixed with 42 per cent of water by weight of cement and of tension tests of 1:3 standard sand briquets from the same cements.

2. A comparison of the neat cement strengths (tension and compression) and standard sand briquet strengths.

3. Data to determine the value of the three tests of cement (neat cement compression specimens, neat cement tension specimens, and standard sand mortar briquets) as a measure or indication of the strength of a cement in concrete.

4. Data on which to base a possible specification requirement for cement strength at 3, 7 and 28 days when tested in fluid cement-water mixtures or in standard sand briquets at 3 days. The advantages of securing a 3-day strength specification for cement are obvious.

This is one of the most comprehensive investigations which has ever been carried out on portland cements. The complete program of tests as outlined in Table I included approximately 18,000 each of tension tests of mortar briquets, tension tests of neat briquets, and compression tests of fluid mixtures, about 1300 compression tests of concrete and 6000 miscellaneous tests of cements and aggregates—a total of about 62,000 tests.

COOPERATING LABORATORIES

The 47 laboratories which cooperated in the investigation, are listed in Table II under the following classifications:

(A) Commercial	6
(B) Government, State and Municipal	19
(C) Portland Cement Manufacturers	13
(D) Railroad	1
(E) University and College	8
Total	47

In so far as possible it was the intention of the sub-committee to have each section of the country represented. The laboratories were widely distributed and may be considered representative of their respective classifications

All of the 47 cooperating laboratories were requested to make the tests on 1:3 standard sand mortar and neat cement and the miscellaneous tests on cement indicated in the Outline of Tests (Table I). Seven laboratories made the tests on concrete and miscellaneous tests

TABLE II.—COOPERATING LABORATORIES.

Name	Address	Individual
GROUP (A) COMMERCIAL TESTING LABORATORIES (6)		
Conwell, E. L., and Co	2024 Arch St., Philadelphia, Pa	E. L. Conwell
Pierce Testing Laboratory	Denver, Colo	Geo. Pierce
Pittsburgh Testing Laboratory	Locust St., Pittsburgh, Pa	A. R. Ellis
Pittsburgh Testing Laboratory	Birmingham, Ala	A. R. Ellis
Thompson and Lichtner Co	Statler Bldg., Boston, Mass	M. N. Clair
Twining Laboratories	2146 Merced St., Fresno, Calif	F. E. Twining
GROUP (B) GOVERNMENT, STATE AND MUNICIPAL (19)		
Baltimore Bureau of Standards	22-24 Harrison St., Baltimore, Md	Conrad Zieget, Jr.
California Highway Commission	3435 Serra Way, Sacramento, Calif	F. T. Maddocks
Hydro-Electric Power Commission	Toronto, Ont., Canada	W. P. Dobson
Illinois Division of Highways	Springfield, Ill	V. L. Glover
Indiana State Highway Commission	Indianapolis, Ind	P. D. Meisenhelder
Iowa State Highway Commission[a]	Ames, Iowa	R. W. Crum
Los Angeles City Engineering Dept	Los Angeles, Calif	T. A. Fitch
Minnesota Dept. of Highways	1246 University Ave., St. Paul, Minn	F. C. Lang
New Hampshire Highway Dept	State House, Concord, N. H	W. F. Purrington
New Jersey Highway Commission	Trenton, N. J	W. A. Johnson
New York Board of Water Supply	2224 Municipal Bldg., New York, N. Y	Thaddeus Merriman
Pennsylvania Dept. of Highways[a]	Harrisburg, Pa	H. S. Mattimore
Philadelphia Dept. of Public Works	City Hall, Philadelphia, Pa	A. F. Burbidge
Portland Bureau of Standards	106 City Hall, Portland, Ore	O. Beck
Rochester, City of	34 Court St., Rochester, N. Y	H. L. Howe
St. Paul, City of	St. Paul, Minn	V. H. Roehrich
U. S. Bureau of Public Roads	Washington, D. C	E. F. Kelley
U. S. Bureau of Standards[a]	Washington, D. C	P. H. Bates
Washington Highway Dept	Olympia, Wash	E. R. Hoffman
GROUP (C) PORTLAND CEMENT MANUFACTURERS (13)		
Alpha Portland Cement Co	Easton, Pa	L. Anderson, Jr.
Atlas Portland Cement Co	Northampton, Pa	T. A. Hicks
International Cement Corp	Hudson, N. Y	H. R. Durbin
Lehigh Portland Cement Co.[a]	Allentown, Pa	Ernest Ashton
Marquette Cement Mfg. Co	LaSalle, Ill	C. M. Butler
Nazareth Cement Co	Nazareth, Pa	E. E. Dreisbach
North American Cement Corp	Security, Md	G. A. Witte
Pennsylvania-Dixie Cement Corp	Richard City, Tenn	A. E. Legg
Portland Cement Association[a]	Chicago, Ill	H. F. Gonnerman
San Antonio Portland Cement Co	San Antonio, Tex	C. Baumberger
Southwestern Portland Cement Co	Osborn, Ohio	R. R. Coghlan
Superior Portland Cement, Inc	Concrete, Wash	H. A. Ambler
Universal Portland Cement Co	Chicago, Ill	O. L. Moore.
GROUP (D) RAILROAD (1)		
New York Central R. R. Co	466 Lexington Ave., New York, N. Y	C. R. Kinsey
GROUP (E) UNIVERSITY AND COLLEGE (8)		
Colorado, University of	Boulder, Colo	H. J. Gilkey
Cornell University[a]	Ithaca, N. Y	H. H. Scofield
Illinois, University of[a]	Urbana, Ill	A. N. Talbot.
Maine, University of	Orono, Maine	H. W. Leavitt
Oregon State Agricultural College	Corvallis, Ore	S. H. Graf
Pennsylvania, University of	Philadelphia, Pa	H. C. Berry
Purdue University	Lafayette, Ind	R. B. Crepps
Washington, University of	Seattle, Wash	I. L. Collier

[a] These laboratories made concrete tests in addition to the cement tests.

of aggregate in addition to the tests on standard sand mortar, neat cement pastes and miscellaneous tests of cement. Five laboratories made chemical analyses of the cements, two laboratories carried out tests on 1:2 standard sand mortars mixed with 42 per cent of water by weight of cement. One laboratory made time of setting tests and two laboratories soundness tests on fluid cement-water mixtures.

MATERIALS

Cement Samples.—For these tests, 25 sacks each of 32 lots of portland cement from as many different mills were purchased from dealers and collected at Chicago. It was the intention to secure samples from fresh warehouse stock and so far as is known the samples used were so obtained. The cements used represent practically all of the important producing centers and include a wide variety of raw materials and manufacturing processes; 22 of the cements were from mills east of the Mississippi River and 10 were from mills west of the Mississippi.

As the sub-committee had no funds to meet the expense of collecting, preparing and distributing the samples, this expense was borne by the Portland Cement Association. At the request of the sub-committee, the Research Laboratory of the Portland Cement Association assumed the responsibility of collecting, sampling and distributing the cements and compiling the test data; the cements were secured through field representatives of the Association and were shipped to Chicago in double cloth sacks by local freight.

The 32 cements were sampled and prepared for shipment as follows:

> Six or seven sacks of a given brand were mixed for 5 minutes in a Blystone concrete mixer and then placed in large metal containers. After mixing the 25 sacks of a single brand in this way, 8 or 9 containers of the mixed cement were obtained. From each of these containers a scoopful of cement weighing 3 to 4 lb. was taken with a confectioner's scoop and placed in a tin can of approximately 30-lb. capacity. The 30 lb. of cement constituted the test sample and after filling the cans, the lids were pressed firmly into place and lightly soldered to prevent removal during shipment; 32 such cans, one for each cement, were shipped to the various laboratories by prepaid freight in wood boxes containing 8 cans each.

Each of the 32 cements was sampled following the above procedure. The laboratories making both cement and concrete tests were furnished with 70-lb. samples prepared in the same way. In this case the cements were placed in 5-ply paper sacks which were in turn placed in double cloth sacks for shipment.

The cements were identified by number and the number was placed in each can or paper sack and also painted on the outside of the package. Every care was taken to insure delivery of the cement samples in good condition and properly identified.

Aggregates for Concrete.—The laboratories making compression tests of 6 by 12-in. concrete cylinders used their local aggregates in making the concrete specimens. Data of tests of the aggregate materials used are given in Table VIII.

METHODS OF MAKING, CURING AND TESTING CEMENT AND CONCRETE SPECIMENS

Accompanying the Outline of Tests sent to each laboratory on December 23, 1926, were detailed instructions concerning the methods to be followed in carrying out the cement and concrete tests. Following, in condensed form, are the principal features of the instructions for making the tests on 1:3 standard sand mortar, fluid cement-water mixtures and concrete:

Tests of 1:3 Standard Sand Briquets.—Standard sand mortar briquets shall be molded and tested in accordance with the A.S.T.M. Standard Specifications and Tests for Portland Cement (C 9 – 26) and the Manual of Cement Testing.[1]

For the sake of uniformity in test procedure, it was recommended that the 1:3 standard sand briquets be troweled and covered with wet burlap and oilcloth immediately after molding, as described below for the neat cement specimens, omitting covering with plate glass.

Fluid Cement-Water Mixture Tests.—The following procedure was recommended in making the fluid cement-water mixture tests, based largely on the experience gained in previous tests of such mixtures described in the reports referred to above:

> *Quantity of Mixing Water.*—Forty-two per cent water by weight of the cement shall be used for all cements, as earlier investigations show that this is the percentage of water necessary to produce the consistency best suited for strength tests on fluid cement-water mixtures.
>
> *Mixing Paste.*—1400 g. of cement shall be used for a batch. Cement-water mixtures shall be mixed in an 8-in. metal stew pan with an 11-in. metal spoon as follows: Place 588 cc. of water in the pan and add 1400 g. of cement. Allow 1 minute for absorption of water, then mix vigorously with the spoon for 1 minute by a stirring and beating action. Before mixing the paste, immerse the mixing pan in clean water and wipe inside with a damp cloth.
>
> The temperature of the room and mixing water shall be maintained as nearly as is practicable at 70° F.
>
> *Molding Specimens.*—Immediately after mixing, the paste shall be poured into the 2-in. cube (or 2 by 4-in. cylinder) and briquet molds.

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 23.

The molds shall be placed on a plane, non-absorbent surface. The paste shall be stirred with a spoon during the pouring operation. Fill each of the 3 molds in a set one-half full and then fill each in turn to overflowing. Immediately after molding, specimens shall be covered with 2 thicknesses of heavy wet burlap; the wet burlap shall in turn be covered with a sheet of oilcloth to minimize evaporation. Care shall be taken to prevent the burlap from touching the specimens. A light wooden frame with loose cross-pieces will serve to keep the burlap away from the freshly-molded specimens. The moist closet is not used in this test.

The 2-in. cube is recommended for the compression test since it may be tested on a side, thus avoiding the necessity of capping. If 2 by 4-in. cylinders are tested, the capping must be carefully done on account of the shrinkage in the fluid cement-water mixtures. This detail exerts a most important influence on the resulting strength.

Three or four hours after molding, the cubes and neat cement briquets shall be struck off with a pointing trowel and covered with plate glass. The wet burlap and oilcloth covering shall be replaced. In case 2 by 4-in. cylinders are used, they shall be struck off with a pointing trowel three or four hours after molding, capped with neat cement mixed with about 35 per cent of water and covered with wet burlap and oilcloth. The cement for capping should be mixed before mixing the test batches and set aside in a covered pan for later use.

Curing.—The specimens shall be removed from the molds 18 to 20 hours after molding, and placed in water at a temperature of 70° F. ±5° F. until tested. The storage water should either be slowly circulating or be changed frequently. The specimens should at all times be covered with wet burlap or in water to avoid exposure to the drying action of the warm room.

Testing.—All specimens shall be tested damp, the 2-in. cubes being *tested on a side*, that is, perpendicular to the direction of molding. During the testing, a spherical bearing block shall be used which shall be carefully centered on top of the specimen. In order to aid in preventing eccentricity of loading, the diameter of the surface of the spherical block bearing on the specimen should not be much larger than 2 in.; it is extremely difficult to center small specimens under large bearing blocks. The moving head of the testing machine shall travel at the rate of about 0.05 in. per minute when the machine is running idle.

Compression Tests of Concrete.—So far as possible, the concrete tests shall be made in accordance with the A.S.T.M. Standard Methods of Making Compression Tests of Concrete (C 39 – 25).

Fine Aggregate shall consist of local concrete sand, graded up to the No. 8 or No. 4 sieve.

Coarse Aggregate shall consist of gravel or crushed stone graded up to 1 or 1½ in.

Aggregates shall be room-dry when used. Absorption of water by both fine and coarse aggregate at ½, 1, 2, 6 and 24 hours shall be determined in order to obtain data by which to calculate the amount of mixing water absorbed by the aggregate.

Sieve analysis, unit weight, silt, colorimetric and specific gravity tests of the aggregates shall be made from time to time during the making of the concrete specimens in accordance with the A.S.T.M. Standard Methods of Test for Unit Weight of Aggregate for Concrete (C 29 - 21), for Organic Impurities in Sands for Concrete (C 40 - 22), for Sieve Analysis of Aggregates for Concrete (C 41 - 24), for Apparent Specific Gravity of Coarse Aggregates (D 30 - 18), for Apparent Specific Gravity of Sand, Stone and Slag Screenings, and Other Fine Non-Bituminous Highway Materials (D 55 - 25), for Quantity of Clay and Silt in Gravel for Highway Construction (D 72 - 21), and the A.S.T.M. Tentative Method of Decantation Test for Sand and Other Fine Aggregates (D 136 - 22 T). In making absorption tests on fine and coarse aggregates, the methods outlined on pages 301 and 302 of Part I of the Proceedings of the Society for 1920 or the methods given in U. S. Department of Agriculture *Bulletin 1216*, "Tentative Standard Methods of Sampling and Testing Highway Materials," may be followed.

Mixing Water.—For the sake of uniformity, all laboratories should use the same amount of mixing water for each cement. Mixing water should be at about 70° F.

Mixing.—The following quantities shall be mixed in each batch, and will give sufficient concrete for one 6 by 12-in. cylinder:

Material	Proportions by Weight	Quantities for Batch	
		pounds	grams
Cement	1.0	5.0	2270
Water	...	3.0	1360
Sand	2.4	12.0	5450
Coarse Aggregate	3.6	18.0	8170

Concrete shall be mixed by hand in a shallow metal pan using a 10-in. bricklayer's trowel blunted by cutting off 2 in. of the point. The cement and fine aggregate shall be mixed dry until of a homogeneous color. The coarse aggregate shall be added and mixed dry and the water then added and the mass thoroughly mixed until of uniform appearance.

Flow Tests for workability of the concrete shall be made immediately after mixing, using fifteen ½-in. drops in 10 seconds. The concrete for the flow test shall be molded in a truncated cone, 5 in. high, top diameter 6¾ in., bottom diameter 10 in., using a ⅝-in. round, bullet-pointed, hard-rubber rod for lightly puddling the concrete into place. The spread of the fresh concrete as compared with the original bottom diameter of the cone expressed as a percentage is the "flow."

Molding Test Cylinders.—Cylinders shall be molded in 6 by 12-in. metal molds resting on machined cast-iron or plate glass base plates. The concrete shall be placed in the molds in 3 layers; each layer shall be rodded 25 times with a ⅝-in. bullet-pointed steel rod and covered with glass or metal plates until capped.

Capping.—Cylinders shall be capped with retempered neat cement 2 to 4 hours after molding, using machined cast-iron or glass cover plates to form the cap.

Curing.—Cylinders shall be removed from the mold after 20 to 48 hours, marked, weighed and placed in a moist room, in damp sand, or

TABLE III.—SUMMARY OF COMPRESSIVE STRENGTHS AND MEAN VARIATIONS FOR 6 BY 12-IN. CONCRETE CYLINDERS.

(*a*) Average Compressive Strengths, lb. per sq. in.

Compression tests of 6 by 12-in. concrete cylinders.
Mix 1:2.4:3.6 by weight (5 lb. cement, 3 lb. water, 12 lb. sand, 18 lb. coarse aggregate per batch).
Hand mixed concrete.

Aggregates from local supplies.
Each value is the average of 3 tests made on different days.

Laboratory	Cements 1–32																																Average	High	Low	Difference	Difference, per cent of Average
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32					
3 Days																																					
No. 35	1760	1420	1340	1080	1660	1350	1340	1190	1170	1120	1270	1260	1540	1290	1390	1370	1550	1010	1220	880	1700	1540	1400	1430	1150	990	1400	780	1430	1150	1230	1080	1290	1760	780	980	76.0
No. 44	1470	1120	960	680	1080	1250	820	830	580	640	870	1060	1140	840	950	810	990	740	830	770	1210	1400	960	1040	930	430	920	570	940	730	840	770	910	1470	430	1040	114.3
Average	1610	1270	1150	880	1370	1300	1080	1010	880	880	1070	1160	1340	1060	1170	1090	1270	880	1020	820	1460	1470	1180	1240	1040	710	1160	680	1180	940	1040	920	1100	1620	600	1020	92.7
Difference	290	300	380	400	580	100	520	360	590	480	400	200	400	450	440	560	560	270	390	110	490	140	440	390	220	560	480	210	490	420	390	310	380	....	....	....	......
Difference, per cent of Average	14.3	23.6	33.0	45.5	42.4	7.7	48.1	35.6	67.0	54.5	37.4	17.2	22.4	42.5	37.6	51.4	44.1	30.7	38.2	13.4	33.6	9.5	37.3	31.4	21.2	79.0	41.4	30.9	41.5	44.7	37.5	33.7	35.9	....	....	....	......
Mean Variation, per cent	7.2	11.8	16.5	22.7	21.2	3.9	24.0	17.8	33.5	27.3	18.7	8.6	11.2	21.2	18.8	26.7	22.0	15.3	19.1	6.7	16.8	4.7	18.7	15.7	10.6	39.5	20.7	15.5	20.8	22.4	18.8	16.8	18.0	....	....	....	......
7 Days																																					
No. 16	2740	2380	1810	1610	2530	2370	2140	1720	2140	1550	2140	1920	2060	1920	2090	2010	2160	1590	1760	1350	2280	2400	2020	2550	1710	1430	1610	1080	2400	1800	1710	1610	1960	2740	1080	1660	84.5
No. 20	2990	2190	2140	1290	2430	1880	1880	1670	1820	1630	1970	2090	2010	1720	1470	1790	1960	1250	1480	1170	1950	1990	1470	1940	1280	930	1630	1110	1240	1210	1250	1130	1690	2990	930	2060	121.9
No. 30	2900	2180	2040	1600	2480	2180	1930	1860	2100	1630	2250	2100	2590	2010	1960	2040	2280	1650	1870	1230	2300	2610	1740	2310	1710	1120	1860	1280	2080	1870	1740	1790	1980	2900	1120	1780	89.8
No. 35	3230	2450	2280	1740	2600	2340	2350	2000	2150	1960	2060	2070	2440	2250	2220	2330	2700	2050	2110	1450	2830	3000	1970	2440	1790	1820	2150	1300	2430	1900	1910	1680	2190	3230	1300	1930	88.2
No. 43	2270	2020	1620	1400	2010	2200	1620	1470	1570	1350	1810	1820	1870	1710	1690	1420	2070	1240	1440	1050	1900	2210	1890	2090	1380	1120	1680	1190	1740	1550	1290	1490	1650	2270	1050	1220	73.6
No. 44	2520	1970	1750	1290	2110	2100	1480	1450	1430	1290	1770	1750	1870	1640	1510	1520	1850	1180	1340	1110	2070	2370	1420	1800	1390	920	1520	1170	1840	1350	1300	1490	1610	2520	920	1600	99.4
Average	2840	2200	1940	1490	2360	2200	1900	1690	1870	1570	2000	1960	2140	1880	1820	1850	2160	1490	1670	1230	2220	2430	1750	2190	1540	1220	1740	1190	1960	1610	1530	1530	1850	2780	1070	1710	92.4
High	3230	2450	2280	1740	2600	2370	2350	2000	2150	1960	2250	2100	2590	2250	2220	2330	2700	2050	2110	1450	2830	3000	2020	2550	1790	1820	2150	1300	2430	1900	1910	1790	2210	....	....	....	......
Low	2270	1970	1620	1290	2010	1880	1480	1450	1430	1290	1770	1750	1870	1640	1470	1420	1850	1180	1340	1050	1900	1990	1420	1800	1280	920	1520	1080	1240	1210	1250	1130	1520	....	....	....	......
Difference	960	480	660	450	590	490	870	550	720	670	480	350	720	610	750	910	850	870	770	400	930	1010	600	750	510	900	630	220	1190	690	660	660	690	....	....	....	......
Difference, per cent of Average	33.8	21.8	34.0	30.2	25.0	22.2	45.7	32.7	38.7	42.7	24.0	17.9	35.0	32.4	41.2	49.2	39.4	58.4	46.1	32.6	41.8	41.5	34.3	34.3	33.1	73.8	36.2	18.5	60.8	42.9	43.8	43.1	37.3	....	....	....	......
Mean Variation, lb.	266	145	213	162	183	125	240	165	260	172	150	128	250	185	266	275	214	270	247	116	248	250	208	245	194	267	175	68	348	243	253	161	211	....	....	....	......
Mean Variation, per cent	9.9	6.6	11.0	10.9	7.8	5.7	12.6	9.8	13.9	11.0	7.5	6.5	11.7	9.8	14.6	14.9	9.9	18.1	14.8	9.4	11.2	10.3	11.9	11.2	12.6	21.9	10.0	5.7	17.8	15.1	16.5	10.5	11.6	....	....	....	......
28 Days																																					
No. 16	4350	3860	3340	2660	3970	3920	3500	3480	3340	2830	3570	3170	3930	3650	3540	3370	3990	3290	3380	2460	3590	4140	3460	3950	3100	2400	2790	2440	3750	3090	3370	3120	3400	4350	2400	1950	57.4
No. 20	3850	3810	2840	2580	3860	3300	3300	2990	3420	2970	3240	3070	3090	2930	2900	2870	3370	2680	2670	2280	3080	3820	2820	3010	2390	1720	2290	2040	2670	2450	2780	2560	2930	3860	1720	2140	73.2
No. 30	3950	3280	3440	2620	3390	3150	3090	3490	2980	2830	3250	3250	4060	3400	3220	3450	3760	2770	2890	2390	3390	3870	2870	3690	3180	2210	3060	2570	3380	3090	3150	3160	3200	4060	2210	1850	57.9
No. 35	5040	3490	4200	3150	3780	4180	3750	4080	3870	3800	3670	3010	4750	4520	4290	3910	4710	4170	3870	2800	4440	5070	3660	4140	3570	3110	3570	3000	3910	3790	3210	3400	3870	5070	2800	2270	58.7
No. 43	2970	3010	2440	2180	2940	2830	2590	2350	2420	2140	2860	2760	2940	2430	2750	2510	2840	2340	2040	2030	2760	2590	2760	2760	2230	1690	2360	1950	2720	2260	2360	2540	2510	3010	1690	1320	52.6
No. 44	3850	3450	2940	2440	3350	3180	3070	2780	2510	2380	2860	2500	3420	2710	3030	2760	3300	2400	2400	2220	3160	3770	2650	2800	2650	1700	2450	2240	3110	2350	2840	2420	2800	3850	1700	2150	76.8
Average	4000	3500	3200	2610	3550	3430	3220	3200	3090	2820	3240	2960	3700	3270	3290	3140	3660	2940	2880	2360	3400	3880	3040	3390	2850	2140	2750	2370	3260	2840	2950	2870	3120	4030	2090	1940	62.2
High	5040	3860	4200	3150	3970	4180	3750	4080	3870	3800	3670	3250	4750	4520	4290	3910	4710	4170	3870	2800	4440	5070	3660	4140	3570	3100	3570	3000	3910	3790	3370	3400	3900	....	....	....	......
Low	2970	3010	2440	2180	2940	2830	2590	2350	2420	2140	2860	2500	2940	2430	2750	2510	2840	2340	2040	2030	2760	2590	2650	2760	2230	1690	2290	1950	2670	2260	2360	2420	2490	....	....	....	......
Difference	2070	850	1760	970	1030	1350	1160	1730	1450	1660	810	750	1810	2090	1540	1400	1870	1830	1830	770	1680	2480	1010	1380	1340	1410	1280	1050	1240	1530	1010	980	1410	....	....	....	......
Difference, per cent of Average	51.7	24.3	55.0	37.2	29.0	39.4	36.0	54.0	47.0	58.9	25.0	25.4	48.9	64.0	46.8	45.0	51.1	62.2	63.5	32.6	49.5	64.0	33.2	40.7	47.0	65.8	46.5	86.5	38.0	53.8	34.2	34.2	45.2	....	....	....	......
Mean Variation, lb.	462	240	460	205	322	417	300	488	453	377	255	220	549	583	418	432	491	525	505	187	407	487	350	535	430	435	386	298	423	485	292	360	401	....	....	....	......
Mean Variation, per cent	12.9	6.9	14.4	7.9	9.1	12.2	9.3	15.3	14.7	13.4	7.9	7.4	14.8	17.8	12.7	13.8	13.4	17.9	17.5	7.9	12.0	12.6	11.5	15.8	15.1	20.4	14.0	12.6	13.0	17.1	9.9	12.5	12.9	....	....	....	......

cent of Average..	51.7	24.3	55.0																			
Mean Variation lb.....	462	240	460	205	322	417	300	488	453	377	255	220	549	583	418							
Mean Variation per cent	12.9	6.9	14.4	7.9	9.1	12.2	9.3	15.3	14.7	13.4	7.9	7.4	14.8	17.8	12.7	13.8	13.4	17.9	17.5	7.9	12.0	12.6

(*b*) Mean Variations in Compressive Strength.

Mean variations are the average deviations of the 3 cylinders from a given cement from their average expressed as a percentage of the average.

Laboratory	Cements 1-32																																Average	High	Low		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32					
3-Day Tests																																					
No. 35	3.8	7.7	1.2	2.5	8.2	7.6	7.7	.1	10.5	5.0	9.2	3.7	1.5	3.4	8.6	8.6	2.4	17.4	9.3	9.4	4.3	6.3	4.8	6.1	4.3	6.4	2.2	6.4	5.4	4.1	8.1	5.2	6.2	17.4	1.2	....	......
No. 44	2.7	8.3	5.2	8.3	16.3	6.9	7.7	10.8	7.5	5.2	3.1	1.9	5.6	4.4	9.5	3.7	0	5.0	4.4	4.8	4.7	6.4	8.3	13.1	4.7	11.6	3.6	12.8	2.5	16.0	10.7	9.1	7.0	16.3	0.0	....	......
Average	3.2	8.0	3.2	5.4	12.2	7.2	7.7	9.4	9.0	5.1	6.2	2.8	3.6	3.9	9.0	6.2	1.2	11.2	6.9	7.1	4.5	6.4	6.9	9.6	4.5	9.0	2.9	9.6	4.0	10.0	9.4	7.2	6.6	16.6	0.6	....	......
7-Day Tests																																					
No. 16	4.4	2.7	0.2	1.0	1.2	2.9	2.8	3.1	2.3	2.4	3.7	3.3	7.3	1.0	1.9	6.1	6.3	4.4	0.9	1.2	2.5	2.6	3.0	10.2	4.9	5.6	7.2	5.6	4.7	3.9	3.9	8.9	3.8	10.2	0.2	....	......
No. 20	2.8	5.2	5.3	15.2	5.5	3.7	3.7	8.2	9.2	7.4	2.9	16.3	6.6	9.5	2.5	2.0	10.4	10.6	2.5	7.7	7.7	6.2	0.7	7.4	5.7	6.1	1.4	2.7	4.0	3.0	12.0	3.8	6.2	16.3	0.7	....	......
No. 30	0.8	6.0	0.7	4.4	2.8	5.3	4.8	4.8	1.9	3.5	2.5	2.1	2.4	2.8	2.2	3.3	0.7	4.6	7.1	0.5	5.9	9.1	2.5	3.2	2.9	2.4	3.2	4.2	4.6	2.0	4.6	0.9	3.4	9.1	0.5	....	......
No. 35	4.4	3.0	3.5	10.5	7.6	3.4	1.5	3.2	9.0	7.3	1.5	16.9	9.2	6.1	3.0	3.3	4.4	9.9	3.6	4.1	4.7	5.2	4.6	7.5	1.3	5.5	23.2	6.9	6.3	7.2	12.6	5.0	6.4	23.2	1.3	....	......
No. 43	6.9	9.8	5.1	3.8	5.0	3.3	3.1	1.8	11.3	5.9	1.7	6.2	10.1	4.1	4.7	4.0	5.5	6.2	3.0	4.1	3.0	3.8	1.8	5.4	10.4	4.5	6.9	1.7	7.8	6.6	12.2	5.6	5.5	12.2	1.7	....	......
No. 44	3.6	12.5	11.1	3.6	3.8	9.2	7.0	8.1	3.3	5.7	7.7	8.6	13.4	9.6	6.2	5.0	2.0	9.6	13.4	2.1	7.7	4.1	1.9	8.5	4.6	15.6	11.9	3.1	4.0	1.7	5.9	11.9	7.1	13.4	1.9	....	......
Average	3.7	6.5	4.3	4.7	4.3	4.6	3.8	4.9	6.2	5.2	3.3	7.2	8.2	5.5	3.4	4.0	4.9	7.6	5.1	3.3	5.2	5.2	2.4	7.0	5.0	6.6	9.0	4.0	5.2	4.1	8.5	6.0	5.3	14.1	1.0	....	......
High	6.9	12.5	11.1	15.2	7.6	9.2	7.0	8.2	11.3	7.4	7.7	16.9	13.4	9.6	6.2	6.1	10.4	10.6	13.4	7.7	7.7	9.1	4.6	10.2	10.4	15.6	23.2	6.9	7.8	7.2	12.6	11.9	10.2	....	....	....	......
Low	0.8	2.7	0.2	1.0	1.2	2.9	1.5	1.8	1.9	2.4	1.5	2.1	2.4	1.0	1.9	2.0	0.7	4.4	0.9	0.5	2.5	2.6	0.7	3.2	2.9	2.4	1.4	1.7	4.0	1.7	3.9	0.9	1.9	....	....	....	......
28-Day Tests																																					
No. 16	3.2	5.2	3.3	4.6	3.6	4.2	1.1	2.6	5.3	1.9	1.4	1.6	2.3	1.5	0.7	1.1	1.6	3.3	3.1	3.6	2.7	3.5	1.6	2.9	4.3	2.1	1.5	1.6	0.4	0.5	3.9	4.6	2.7	5.3	0.4	....	......
No. 20	2.4	1.0	3.3	7.5	6.8	2.9	2.9	1.9	2.0	1.0	8.3	5.8	2.9	1.2	3.3	8.6	3.0	7.8	2.4	2.6	2.3	0.3	6.7	8.6	6.8	9.1	4.5	7.6	11.7	7.9	7.3	13.6	5.1	13.6	0.3	....	......
No. 30	4.0	2.2	2.3	3.3	6.8	1.6	2.9	1.6	1.2	0.2	2.6	4.6	1.7	2.1	3.7	2.5	6.5	4.8	12.7	1.5	2.5	1.5	0.6	1.5	1.2	2.1	1.4	1.7	1.8	1.6	5.8	1.8	2.9	12.7	0.2	....	......
No. 35	5.5	3.1	6.2	9.0	8.1	5.6	10.3	11.7	4.4	2.1	2.2	5.5	11.3	4.0	5.7	13.8	6.9	5.6	10.7	4.2	6.4	3.0	9.7	9.6	6.5	10.1	6.8	7.0	7.1	8.8	1.4	1.3	6.7	13.8	1.3	....	......
No. 43	14.6	4.5	9.4	14.2	10.1	7.2	7.6	4.7	8.7	6.8	2.9	14.6	4.4	19.5	8.2	14.7	4.1	2.0	6.4	2.3	7.3	7.2	5.7	9.0	5.2	9.3	5.9	11.1	4.2	8.7	16.8	2.2	8.1	19.5	2.0	....	......
No. 44	5.3	4.9	8.1	1.6	7.5	6.5	6.9	7.1	14.2	4.1	12.2	6.5	9.5	13.3	9.5	2.8	12.6	5.2	1.8	8.9	3.0	1.9	3.8	8.8	6.8	4.9	10.5	3.9	4.8	6.5	6.0	12.0	6.9	14.2	1.6	....	......
Average	5.8	3.5	5.4	6.7	7.2	4.7	5.3	4.9	6.0	2.7	4.9	6.4	5.4	6.9	5.2	7.2	5.8	4.8	6.2	3.9	4.0	2.9	4.7	6.7	5.1	6.3	5.1	5.5	5.0	5.7	6.9	5.9	5.4	13.2	1.0	....	......
High	14.6	5.2	9.4	14.2	10.1	7.2	10.3	11.7	14.2	6.8	12.2	14.6	11.3	19.5	9.5	14.7	12.6	7.8	12.7	8.9	7.3	7.2	9.7	9.6	6.8	10.1	10.5	11.1	11.7	8.8	16.8	13.6	11.0	....	....	....	......
Low	2.4	1.0	2.3	1.6	3.6	1.6	1.1	1.6	1.2	0.2	1.4	1.6	1.7	1.2	0.7	1.1	1.6	2.0	1.8	1.5	2.3	0.3	0.6	1.5	1.2	2.1	1.4	1.6	0.4	0.5	1.4	1.3	1.4	....	....	....	......

TABLE IV.—SUMMARY OF TENSILE STRENGTHS AND MEAN VARIATIONS FOR 1:3 STANDARD SAND BRIQUETS.

(*a*) Average Tensile Strengths of 1:3 Standard Sand Briquets for each group of Laboratories, lb. per sq. in.

Briquets made in accordance with the A.S.T.M. Standard Specifications and Tests for Portland Cement (Serial Designation: C 9 - 26).

Laboratory	Number Reporting	Cements 1–32																																Average Value	High Value	Low Value	Difference	Difference, per cent of Average
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32					
3-DAY TESTS																																						
Commercial	5	265	235	200	180	230	215	220	185	180	175	200	235	245	195	215	210	230	190	185	165	245	255	230	260	200	175	230	165	235	180	210	195	210	265	165	100	47.5
Government, State and Municipal	19	275	235	210	185	250	230	220	205	195	190	205	230	250	205	210	200	220	175	185	150	255	250	220	250	200	175	220	170	245	200	210	195	215	275	150	125	58.1
Portland Cement Manufacturers	13	285	260	220	205	270	240	250	230	215	215	230	250	280	225	230	220	235	200	195	175	275	270	230	270	210	200	250	180	255	210	230	220	230	285	175	110	47.8
Railroad	1	290	220	210	210	225	220	245	225	200	190	195	240	245	205	230	220	215	200	195	193	260	280	220	245	225	240	235	175	270	210	165	170	220	290	165	125	56.8
University and College	8	265	215	190	165	230	220	215	190	180	175	200	220	230	200	195	195	220	175	180	145	235	235	205	255	200	175	220	160	235	175	200	190	200	265	145	120	60.0
Weighted average	46	275	240	210	190	250	230	230	205	195	195	210	235	255	205	215	205	220	185	185	160	255	255	220	260	205	180	230	170	245	195	210	200	215	**275**	**160**	115	53.5
7-DAY TESTS																																						
Commercial	5	325	315	250	240	300	320	300	250	270	250	285	290	325	280	285	270	280	255	245	245	330	335	275	335	260	245	275	215	305	260	270	270	280	335	215	120	42.9
Government, State and Municipal	19	350	335	265	255	310	305	310	280	285	255	290	305	325	275	290	265	285	260	260	225	320	325	285	330	270	260	290	230	320	265	265	260	285	350	225	125	43.8
Portland Cement Manufacturers	13	375	350	280	285	340	320	340	310	320	285	320	320	350	300	310	290	315	280	275	250	340	345	300	360	300	290	305	245	345	280	290	285	310	375	245	130	41.9
Railroad	1	355	320	245	260	305	290	280	270	300	260	280	325	315	315	290	285	275	255	285	270	320	330	310	300	275	260	290	260	315	280	270	225	290	355	255	100	34.5
University and College	8	325	305	235	235	295	295	285	280	270	250	280	290	300	275	260	250	285	245	255	215	295	300	275	320	260	250	275	215	305	245	265	245	270	325	215	110	40.7
Weighted average	46	350	330	260	260	315	310	310	285	290	255	295	305	330	285	290	270	290	260	260	235	325	325	285	335	270	265	290	230	325	265	275	265	290	**350**	**230**	120	41.4
28-DAY TESTS																																						
Commercial	5	425	440	360	355	390	400	395	385	365	355	355	385	430	390	370	385	400	360	370	370	405	415	375	415	360	355	355	335	400	355	370	390	385	440	335	105	27.3
Government, State and Municipal	19	445	435	370	355	390	400	400	410	375	370	385	395	425	390	380	365	370	375	370	355	400	400	385	400	385	375	380	345	415	360	380	370	385	445	345	100	26.0
Portland Cement Manufacturers	13	460	450	405	405	425	420	430	420	400	405	420	405	455	430	400	395	410	400	385	390	430	435	405	430	425	400	400	365	435	390	390	390	415	460	365	95	22.9
Railroad	1	415	475	395	375	385	375	410	410	395	395	400	410	425	365	400	395	355	375	390	350	385	425	440	420	360	395	340	350	430	315	360	385	390	475	315	160	41.0
University and College	8	430	420	355	345	360	380	395	375	360	350	380	375	410	390	370	360	365	360	365	330	380	385	370	380	375	350	365	325	410	350	355	345	370	430	325	105	28.4
Weighted average	46	445	440	375	370	395	400	405	405	380	375	390	390	430	400	385	375	385	375	375	360	405	410	390	405	390	375	380	345	420	365	380	375	390	**445**	**345**	100	25.6
3-MONTH TESTS																																						
Commercial	5	470	485	455	395	435	405	435	415	400	410	390	425	475	430	410	410	425	395	415	425	450	445	430	425	435	410	415	415	440	430	410	435	425	485	390	95	22.4
Government, State and Municipal	19	460	480	455	410	415	400	420	450	400	430	415	445	475	440	415	405	410	390	415	450	450	435	445	425	440	445	435	450	445	415	430	440	430	480	390	90	20.8
Portland Cement Manufacturers	13	455	495	470	435	430	435	435	460	410	430	430	455	495	475	425	425	425	410	425	465	455	435	445	435	455	455	440	440	455	420	415	455	445	495	410	85	19.1
Railroad	1	465	475	430	425	385	385	465	430	340	380	355	455	410	445	365	365	365	365	360	470	395	420	425	385	400	395	375	400	400	360	365	365	400	475	340	135	33.7
University and College	8	450	485	430	385	395	405	420	425	395	420	410	425	460	445	405	405	405	390	410	430	435	410	425	425	440	420	425	430	450	390	400	425	420	485	385	100	23.8
Weighted average	46	460	485	455	410	415	410	425	445	400	420	415	440	475	450	415	410	415	395	415	450	450	430	440	425	445	445	430	440	450	410	410	440	430	**485**	**395**	90	20.8

NOTE.—The values given in bold-face figures are the high and low values of the weighted averages, and not the average of the high and low values for the individual groups.

(*b*) Average Mean Variations in Tensile Strength of the three 1:3 Standard Sand Briquets from a batch for each group of laboratories.

Laboratory	Number Reporting	Cements 1-32																																Average Value	High Value	Low Value	Difference
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32				
3-Day Tests																																					
Commercial	5	1.1	2.4	3.1	3.6	2.5	2.8	2.8	3.6	3.2	3.5	5.4	3.7	3.7	2.9	2.7	2.9	2.5	2.1	3.0	1.5	2.4	1.7	3.6	2.0	2.9	2.5	2.8	3.9	5.4	4.0	6.0	5.0	3.2	6.0	1.1	4.9
Government, State and Municipal	19	4.5	4.4	4.4	4.6	3.7	4.2	3.7	3.3	4.5	4.6	4.5	5.0	4.2	3.9	4.4	4.2	5.3	5.1	4.3	5.2	3.8	3.8	4.5	4.4	3.3	5.3	3.2	5.0	4.9	3.5	4.5	5.8	4.4	5.8	3.2	2.6
Portland Cement Manufacturers	13	3.7	3.2	3.4	4.8	4.6	3.7	3.4	3.3	3.8	4.0	4.0	3.7	4.0	2.6	4.1	2.9	4.4	4.3	3.7	3.8	4.4	3.9	3.2	4.9	3.8	3.9	3.3	4.2	4.1	3.3	4.7	4.2	3.9	4.9	2.6	2.3
Railroad	1	6.3	9.1	2.4	4.0	5.9	6.1	2.0	0.7	4.2	6.1	4.3	6.2	2.0	5.7	8.0	5.3	4.6	5.8	6.8	6.0	1.9	6.0	6.8	3.4	5.9	4.9	5.7	8.6	8.0	5.6	6.1	0	5.1	9.1	0	9.1
University and College	8	3.6	4.5	6.3	4.4	4.0	3.7	4.2	3.7	5.5	5.6	6.2	4.1	6.1	5.2	4.6	5.5	6.5	4.8	4.8	5.9	5.6	4.1	4.6	3.9	5.1	5.1	5.6	4.0	4.2	3.4	6.5	5.0	4.9	6.5	3.4	3.1
Weighted average	46	3.8	4.0	4.2	4.5	3.9	3.9	3.6	3.3	4.3	4.5	4.8	4.3	4.4	3.7	4.2	4.0	4.9	4.5	4.1	4.6	4.1	3.7	4.1	4.1	3.8	4.6	3.7	4.6	4.7	3.6	5.1	5.0	4.2	5.1	3.3	1.8
7-Day Tests																																					
Commercial	5	1.2	2.8	3.4	2.0	2.7	3.2	2.0	4.7	2.5	3.0	2.7	4.0	3.6	3.4	1.8	2.6	2.4	3.9	1.9	3.1	2.7	4.5	2.6	3.3	2.5	3.4	2.7	4.4	3.1	2.7	2.5	3.6	3.0	4.7	1.2	3.5
Government, State and Municipal	19	4.2	4.0	4.4	3.9	4.3	4.8	3.9	3.6	3.2	4.1	3.9	3.9	3.0	4.3	3.8	3.3	4.4	4.4	4.9	5.8	4.6	4.5	5.0	3.5	4.8	4.6	3.9	4.0	3.7	4.6	3.7	4.1	4.2	5.8	3.0	2.8
Portland Cement Manufacturers	13	3.5	4.5	3.6	3.0	4.1	3.3	3.4	3.9	4.8	4.4	3.5	3.3	3.6	3.0	3.6	3.4	3.9	3.3	3.8	3.3	2.9	3.5	3.8	3.4	3.8	2.8	3.0	3.4	3.4	3.3	4.0	4.3	3.6	4.8	2.8	2.0
Railroad	1	4.7	3.6	9.6	7.0	4.9	3.4	2.4	4.9	3.3	5.8	3.0	3.1	1.1	3.2	4.0	3.5	3.0	5.2	6.4	1.9	3.6	3.5	2.1	1.7	5.5	5.8	0.6	1.3	4.8	8.9	1.8	6.7	4.1	9.6	0.6	9.0
University and College	8	5.4	4.4	8.1	4.3	4.0	4.3	6.8	4.8	4.6	4.6	5.1	5.2	3.7	3.7	5.0	3.4	4.0	4.0	3.7	2.2	5.6	3.8	4.1	3.7	4.1	4.4	3.5	3.6	4.1	4.3	4.3	4.9	4.4	8.1	2.2	5.9
Weighted average	46	3.8	4.1	4.8	3.6	4.0	4.1	4.0	4.0	3.8	4.2	3.8	4.0	3.3	3.7	3.7	3.3	3.9	4.0	4.1	4.1	4.1	4.1	4.2	3.4	4.2	4.0	3.4	3.7	3.6	4.1	3.7	4.3	3.9	4.8	3.3	1.5
28-Day Tests																																					
Commercial	5	1.8	2.1	2.2	3.1	2.2	2.3	3.4	1.5	2.6	2.3	3.9	2.5	3.8	2.7	2.6	1.8	2.4	1.9	2.6	2.3	2.4	2.8	2.7	1.7	2.4	2.0	2.7	3.3	2.6	2.1	2.2	3.4	2.5	3.9	1.5	2.4
Government, State and Municipal	19	4.2	4.8	3.0	3.8	3.1	3.8	3.3	4.1	4.7	3.9	3.5	2.9	4.4	4.9	3.8	2.7	3.5	3.4	3.8	4.1	3.5	3.8	4.1	3.6	4.9	4.8	3.0	4.0	3.6	3.3	4.0	2.8	3.4	4.9	2.7	2.2
Portland Cement Manufacturers	13	3.5	3.5	2.7	3.5	2.8	3.1	3.1	2.5	2.5	3.6	2.9	4.2	2.3	3.0	3.0	3.6	4.1	2.8	4.0	3.0	2.9	3.3	3.7	3.9	2.9	2.2	2.8	3.0	3.1	3.0	2.6	3.4	3.1	4.2	2.2	2.0
Railroad	1	4.4	3.2	3.0	5.3	3.0	4.4	1.2	3.7	1.3	2.1	6.2	3.7	3.9	5.5	3.3	5.1	10.8	4.0	4.7	2.9	3.5	4.3	2.3	2.0	3.7	4.6	4.4	3.3	4.7	1.9	4.2	4.8	3.9	10.8	1.2	9.6
University and College	8	3.7	4.3	4.3	4.2	2.8	3.8	3.2	3.5	4.2	4.6	3.7	4.0	4.4	3.9	4.8	5.2	4.1	4.1	6.0	4.5	5.1	4.4	3.3	5.4	2.2	4.7	2.8	2.9	3.2	3.7	5.0	3.3	4.1	6.0	2.2	3.8
Weighted average	46	3.6	3.9	3.0	3.7	3.0	3.4	3.2	3.2	3.7	3.7	3.8	3.1	3.7	4.0	3.6	3.3	3.8	3.2	4.2	3.6	3.5	3.7	3.7	3.7	3.6	3.8	2.9	3.4	3.3	3.1	3.6	3.2	3.3	4.2	2.9	1.3
3-Month Tests																																					
Commercial	5	2.4	1.8	2.7	2.4	1.9	3.0	1.8	3.2	1.9	2.7	2.5	2.9	2.2	1.3	4.0	2.5	2.5	2.8	2.7	2.6	2.8	2.0	2.0	1.3	4.0	1.1	3.0	3.5	3.1	4.5	2.5	3.1	2.6	4.5	1.1	3.4
Government, State and Municipal	9	2.9	4.4	4.1	4.2	3.3	4.2	3.7	3.2	2.4	4.0	4.0	4.7	4.0	4.0	4.3	3.6	4.9	2.7	4.4	3.9	4.3	3.1	3.4	4.0	3.6	4.1	3.7	4.0	3.0	4.1	3.9	3.1	3.8	4.9	2.4	2.5
Portland Cement Manufacturers	13	2.6	2.9	2.7	3.8	2.8	2.8	3.3	3.9	3.2	3.3	3.4	3.5	3.9	3.2	3.7	3.7	2.6	3.0	3.4	3.0	4.2	3.4	3.4	1.8	2.5	3.0	3.9	4.3	3.6	3.6	2.4	3.1	3.2	4.3	1.8	2.5
Railroad	1	4.7	4.6	3.9	3.5	4.8	2.6	7.2	3.5	0.5	3.1	6.6	5.1	2.4	0.7	5.0	1.4	2.7	7.3	2.8	0.7	1.3	3.6	4.3	5.2	4.6	4.2	4.9	3.8	1.3	6.5	6.4	5.9	3.9	7.3	0.5	6.8
University and College	8	3.2	3.4	5.0	4.7	3.7	5.1	4.7	4.7	4.3	3.0	3.1	4.2	4.1	4.4	5.4	3.4	3.7	2.7	3.3	4.8	4.5	3.8	5.1	4.3	4.5	5.5	4.0	4.9	4.0	3.0	6.7	4.5	4.2	6.7	2.7	4.0
Weighted average	46	2.8	3.5	3.7	4.0	3.1	3.8	3.7	3.7	2.8	3.5	3.6	4.0	3.8	3.5	4.3	3.4	3.7	2.9	3.7	3.6	4.1	3.2	3.5	3.2	3.5	3.7	3.6	4.2	3.3	3.9	3.8	3.4	3.6	4.3	2.8	1.5

NOTE.—The values given in bold-face figures are the high and low values of the weighted averages, and not the average of the high and low values for the individual groups.

TABLE V.—SUMMARY OF TENSILE STRENGTHS AND MEAN VARIATIONS FOR NEAT CEMENT BRIQUETS.

(*a*) Average Tensile Strengths of Neat Cement Briquets for each group of Laboratories, lb. per sq. in.

All cements mixed with 42 per cent water by weight.

Laboratory	Number Reporting	Cements 1–32																																Average Value	High Value	Low Value	Difference
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32				
3-DAY TESTS																																					
Commercial	6	235	220	190	175	240	200	230	185	180	165	215	215	230	190	220	190	205	165	180	160	240	230	205	265	205	165	230	150	245	205	215	190	205	265	150	115
Government, State and Municipal	19	250	220	180	170	240	210	210	175	180	160	200	210	220	185	210	180	190	155	180	160	250	225	210	245	190	165	215	145	235	200	210	185	200	250	145	105
Portland Cement Manufacturers	13	260	230	190	190	250	220	215	190	195	175	210	235	240	195	215	195	210	175	185	170	250	245	220	250	205	180	225	155	240	210	220	195	210	260	155	105
Railroad	1	380	235	195	205	285	235	225	185	205	165	205	230	250	200	245	175	220	155	220	190	240	245	230	300	210	225	235	155	295	275	275	225	230	380	155	225
University and College	8	240	195	180	155	240	205	185	175	175	155	195	215	220	170	195	175	190	150	175	150	235	220	195	245	200	160	205	155	230	195	205	185	195	245	150	95
Weighted average	47	250	220	185	175	240	210	210	180	185	165	205	220	230	185	210	185	195	160	180	160	245	230	210	250	200	170	220	150	240	205	215	190	200	250	150	100
7-DAY TESTS																																					
Commercial	6	345	340	275	260	350	280	335	265	305	280	285	300	325	290	330	275	310	280	285	240	350	330	300	370	275	255	315	200	330	300	270	255	295	370	200	170
Government, State and Municipal	19	350	315	265	255	245	305	320	350	300	255	290	285	315	280	325	280	295	260	280	240	345	340	300	380	290	270	300	210	320	280	270	255	295	380	210	170
Portland Cement Manufacturers	13	360	340	270	265	360	305	325	285	315	270	325	310	325	295	310	280	300	265	280	250	350	340	300	390	295	275	315	210	325	300	275	260	300	390	210	180
Railroad	1	400	365	285	275	375	350	330	280	325	270	355	305	320	280	355	305	280	230	345	255	400	385	340	445	265	295	375	205	410	405	340	330	330	445	205	240
University and College	8	345	295	270	240	325	315	315	260	340	275	315	325	305	280	315	275	310	260	275	225	350	350	285	395	275	260	300	210	320	290	265	260	290	395	210	185
Weighted average	47	355	320	270	255	350	305	320	305	310	265	305	300	320	285	320	280	300	265	280	240	350	340	300	385	285	270	310	210	325	290	270	260	295	385	210	175
28-DAY TESTS																																					
Commercial	6	445	445	415	425	470	440	465	435	425	405	460	405	450	455	475	415	425	440	410	385	470	450	435	495	415	440	410	360	450	475	390	380	430	495	360	135
Government, State and Municipal	19	490	450	405	420	505	470	485	445	460	410	465	415	475	455	485	440	445	440	460	395	500	460	460	500	410	460	420	370	490	420	410	450	450	505	370	135
Portland Cement Manufacturers	13	470	455	405	415	500	465	490	455	440	415	450	420	440	450	465	435	440	430	450	390	470	455	460	485	420	450	425	365	470	425	400	400	440	500	365	135
Railroad	1	520	520	455	535	615	540	590	485	495	495	560	455	515	500	500	460	565	520	550	440	550	530	520	535	430	540	445	390	565	575	460	465	510	615	390	225
University and College	8	455	405	425	440	485	470	505	455	460	415	475	440	490	470	490	450	455	425	465	390	480	455	455	520	425	460	420	355	480	455	410	415	450	520	355	165
Weighted average	47	475	445	410	425	495	465	490	450	450	410	465	420	465	455	480	435	445	435	450	390	485	460	455	495	425	455	420	365	480	440	405	420	445	495	365	130
3-MONTH TESTS																																					
Commercial	6	490	530	490	495	525	505	520	465	465	520	525	460	475	480	480	480	480	440	485	440	470	460	440	500	490	500	470	435	520	470	430	440	480	530	430	100
Government, State and Municipal	19	510	525	475	525	550	510	530	510	510	500	550	485	510	510	525	465	515	485	515	525	500	490	545	505	510	550	460	475	565	485	480	490	510	565	460	105
Portland Cement Manufacturers	13	480	510	445	515	520	510	475	505	480	500	515	500	495	505	505	475	490	470	500	505	495	475	525	490	490	525	450	460	535	465	475	490	490	535	445	90
Railroad	1	565	625	545	530	625	625	605	460	595	590	570	580	520	595	550	465	525	505	530	500	580	475	570	520	460	585	450	470	505	555	465	460	535	625	450	175
University and College	8	480	505	475	520	535	490	525	490	510	490	540	475	510	520	520	480	505	475	520	515	510	495	510	500	520	510	465	480	550	515	485	500	505	550	465	85
Weighted average	47	495	520	470	505	535	505	515	500	495	505	540	485	500	505	515	475	500	475	505	505	500	480	520	500	505	530	460	465	545	485	475	485	500	545	460	95

NOTE.—The values given in boldface figures are the high and low values of the weighted averages, and are not the average of the high and low values for the individual groups.

(*b*) Average Mean Variations in Tensile Strength of the 3 Neat Cement Briquets from a batch for each group of Laboratories.

Laboratory	Number Reporting	Cements 1–32																																Average Value	High Value	Low Value
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32			
3-DAY TESTS																																				
Commercial	6	4.6	4.4	3.3	4.0	4.1	3.9	2.8	2.2	4.0	6.1	3.4	3.6	3.6	4.5	3.4	4.3	4.3	3.5	3.3	3.1	4.8	2.4	5.3	3.1	3.9	8.4	3.6	2.5	4.1	3.6	2.9	4.2	3.9	8.4	2.2
Government, State and Municipal	19	5.1	4.6	3.9	5.2	6.1	4.0	5.7	4.0	4.9	5.4	4.8	6.5	3.9	4.1	5.3	6.0	4.0	3.9	4.8	3.5	3.6	4.2	4.6	4.3	3.6	5.1	3.7	3.8	4.3	3.8	5.1	4.5	4.6	6.5	3.5
Portland Cement Manufacturers	13	5.2	3.9	4.8	3.4	4.9	4.0	4.2	2.8	3.8	4.5	4.1	4.5	4.1	4.6	4.1	3.1	3.7	4.0	3.4	4.1	3.6	3.4	3.2	3.9	5.5	2.6	4.0	4.1	4.3	4.0	3.8	3.6	4.0	5.5	2.6
Railroad	1	6.1	9.2	5.1	3.2	1.8	7.8	4.4	5.4	4.1	7.1	6.5	5.1	6.0	2.5	2.7	3.8	11.1	4.3	1.5	3.5	8.3	0.7	5.1	6.7	9.5	6.7	12.1	6.4	1.7	3.6	6.7	5.9	5.5	12.1	0.7
University and College	8	8.0	5.7	4.1	3.0	4.8	4.4	6.8	4.6	5.7	5.2	5.8	5.4	6.4	7.0	4.9	5.1	9.6	5.9	3.6	5.5	6.1	6.3	5.5	7.0	4.9	4.7	4.4	6.7	4.5	4.4	4.7	4.9	5.5	9.6	3.0
Weighted average	47	5.5	4.6	4.1	4.1	5.2	4.1	5.0	3.6	4.6	5.2	4.6	5.4	4.4	4.8	4.6	4.8	5.0	4.2	3.9	3.9	4.3	4.0	4.5	4.5	4.5	4.8	4.1	4.2	4.2	3.9	4.4	4.3	4.5	5.5	3.6
7-DAY TESTS																																				
Commercial	6	2.3	4.1	5.2	2.9	3.5	4.8	3.7	2.6	2.2	2.8	4.2	3.2	4.3	4.8	3.6	2.6	3.2	2.6	3.1	4.2	4.1	3.9	4.2	4.6	4.5	2.4	4.3	4.3	4.0	2.7	4.4	4.0	3.7	5.2	2.2
Government, State and Municipal	19	4.6	6.6	4.3	4.7	4.4	5.0	4.3	4.9	4.3	4.7	4.6	6.4	4.0	4.2	3.8	4.0	3.9	3.5	3.3	4.7	3.7	4.0	4.4	3.3	4.0	4.0	3.8	5.2	3.4	4.5	4.0	4.9	4.4	6.6	3.3
Portland Cement Manufacturers	13	2.9	4.1	4.3	4.1	4.0	4.0	3.8	3.7	2.7	3.8	3.2	3.8	4.0	3.7	3.9	4.0	2.6	4.5	4.8	3.8	3.0	4.0	3.8	4.2	2.8	3.4	3.3	3.6	2.9	4.1	2.9	3.9	3.7	4.8	2.6
Railroad	1	2.1	3.2	2.9	2.4	7.6	1.9	7.1	6.0	2.1	6.2	3.3	7.6	4.2	3.0	7.5	4.4	6.0	5.1	2.9	9.2	4.2	10.8	2.9	6.4	2.5	0.6	4.4	0.8	3.8	4.5	1.0	2.5	4.3	10.8	0.6
University and College	8	2.8	4.4	3.6	4.8	5.9	3.0	5.9	5.6	4.7	3.7	4.0	5.5	4.1	5.6	4.4	6.0	5.0	4.5	5.5	5.2	6.1	4.2	5.7	6.6	5.5	6.8	4.7	5.8	6.5	5.6	5.1	3.6	5.0	6.6	2.8
Weighted average	47	3.5	5.1	4.3	4.3	4.5	4.3	4.4	4.4	3.6	4.0	4.0	5.1	4.1	4.4	4.0	4.2	3.7	3.9	4.0	4.6	4.0	4.2	4.4	4.3	4.0	4.0	3.9	4.7	3.8	4.4	3.9	4.3	4.2	5.1	3.5
28-DAY TESTS																																				
Commercial	6	3.4	2.4	5.8	6.1	2.3	3.1	4.2	2.6	3.8	2.8	3.3	2.8	3.1	2.8	1.7	3.0	2.3	2.8	2.4	2.8	2.9	2.7	3.3	4.1	2.3	2.8	4.0	5.4	3.1	2.7	3.1	2.2	3.2	6.1	1.7
Government, State and Municipal	19	5.2	4.4	4.9	3.5	4.8	5.0	4.8	4.7	4.0	4.3	4.5	4.7	4.0	3.8	4.5	5.1	4.7	5.0	4.8	3.9	3.7	4.5	3.9	4.4	3.8	4.6	3.5	4.6	3.6	5.0	4.7	4.0	4.2	5.2	3.5
Portland Cement Manufacturers	13	3.5	3.7	4.3	3.8	3.7	3.2	3.5	3.7	2.7	3.8	3.3	3.5	4.2	2.8	2.7	3.5	3.9	5.3	4.5	4.7	3.5	4.5	4.0	4.0	2.8	2.8	3.3	3.7	4.2	3.8	3.5	4.3	3.7	5.3	2.7
Railroad	1	2.8	6.4	3.3	2.8	4.3	1.2	4.2	4.5	2.7	2.4	5.1	3.7	1.6	4.0	4.7	2.5	4.7	3.8	4.5	6.1	4.2	2.5	4.8	3.7	1.5	4.0	2.2	2.1	5.3	2.3	7.2	1.1	3.6	7.2	1.1
University and College	8	6.5	6.1	5.0	4.8	5.4	4.6	4.2	4.6	4.0	6.0	4.0	5.6	5.4	5.4	4.0	4.5	5.5	5.5	3.6	4.7	7.4	5.6	6.5	3.3	5.3	4.3	5.3	6.8	5.0	4.3	5.6	3.9	5.1	7.4	3.3
Weighted average	47	4.6	4.2	4.8	4.1	4.3	4.1	4.2	4.1	3.6	4.2	4.0	4.2	4.1	3.7	3.6	4.2	4.3	4.9	4.2	4.2	4.2	4.4	4.3	4.1	3.5	3.8	3.8	4.8	4.0	4.2	4.4	3.8	4.2	4.9	3.5
3-MONTH TESTS																																				
Commercial	6	4.5	4.5	4.3	4.5	3.9	4.1	5.1	5.2	4.0	3.4	2.9	3.0	4.7	3.5	4.2	1.9	2.8	2.6	2.5	4.2	4.0	3.6	6.1	4.7	3.7	3.5	2.3	2.7	2.5	3.1	2.5	2.6	3.6	6.1	1.9
Government, State and Municipal	19	6.5	5.7	5.4	4.0	3.6	4.8	5.7	4.9	5.3	5.0	4.1	5.7	6.3	5.1	6.2	5.0	5.3	6.5	5.5	5.4	5.0	3.9	4.7	5.5	4.7	5.5	5.0	4.3	3.7	5.5	5.0	5.5	5.1	6.5	3.6
Portland Cement Manufacturers	13	4.6	3.9	3.7	4.4	5.1	4.2	4.2	4.0	3.5	4.2	3.8	4.9	4.2	3.8	3.7	4.6	4.4	3.6	3.6	5.0	3.3	3.7	4.1	4.4	3.4	3.5	5.0	3.1	4.0	4.5	4.0	3.7	4.1	5.0	3.1
Railroad	1	5.0	5.1	5.8	4.7	0.8	3.5	1.9	3.3	3.9	3.4	6.1	2.0	5.4	3.9	4.2	1.8	0.3	5.6	3.5	4.0	5.5	3.2	5.3	3.8	3.6	4.3	3.3	3.5	4.3	3.3	1.4	7.2	3.8	5.8	0.3
University and College	8	4.5	5.9	5.3	4.7	6.1	5.8	4.9	6.4	5.0	4.6	6.7	7.4	8.3	6.6	8.5	7.2	5.3	4.9	6.5	7.7	3.4	4.3	5.6	6.1	5.2	5.5	6.3	6.3	5.1	4.4	6.0	5.7	5.8	8.5	3.4
Weighted average	47	5.3	5.1	4.8	4.3	4.4	4.7	5.0	4.9	4.6	4.5	4.3	5.4	5.8	4.8	5.6	4.8	4.6	4.9	4.7	5.5	4.1	3.9	4.9	5.2	4.3	4.7	4.8	4.1	3.9	4.7	4.5	4.7	4.7	5.8	3.9

NOTE.—The values given in boldface figures are the high and low values of the weighted averages, and are not the average of the high and low values for the individual groups.

Table VI.—Summary of Compressive Strengths and Mean Variations for Compression Specimens.

(*a*) Average Compressive Strengths of Neat Cement Compression Specimens for each group of Laboratories, lb. per sq. in.

Laboratory	Number Reporting	Cements 1-32																																Average Value	High Value	Low Value	Difference
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32				
3-Day Tests																																					
Commercial	6	2600	1700	1710	1410	2060	1520	2000	1520	1560	1310	1690	1710	1920	1350	2000	1590	2000	1290	1460	1150	2300	2270	1820	2330	1620	1320	2090	1240	1900	1760	1710	1430	1730	2600	1240	1360
Government, State and Municipal	19	2230	1650	1540	1160	1890	1530	1720	1250	1410	1090	1440	1630	1730	1340	1770	1320	1740	1100	1390	1050	2030	2030	1550	1930	1480	1150	1930	1070	1780	1610	1580	1310	1540	2230	1050	1180
Portland Cement Manufacturers	13	2350	1710	1670	1150	2100	1650	1890	1450	1540	1180	1510	1690	1950	1420	1810	1450	1890	1230	1410	1160	2270	2220	1620	2170	1600	1210	2080	1100	1830	1700	1630	1370	1650	2350	1100	1250
Railroad	1	2460	1310	1630	1260	1880	1280	1840	1200	1640	900	1240	1130	1180	1190	1890	1330	2230	1150	1360	1090	2010	1800	1720	2720	1300	1020	1150	770	1290	1300	990	970	1440	2720	770	1950
University and College	8	2140	1600	1570	1070	1940	1500	1680	1250	1490	1160	1480	1580	1740	1340	1640	1310	1690	1120	1340	1010	1970	1990	1490	1970	1450	1180	1920	1030	1690	1520	1410	1280	1510	2140	1010	1130
Weighted average	47	2300	1650	1600	1180	1970	1550	1800	1340	1480	1150	1490	1640	1800	1380	1790	1390	1810	1170	1400	1090	2120	2100	1600	2070	1530	1190	1970	1090	1780	1630	1570	1330	1590	2300	1010	1290
7-Day Tests																																					
Commercial	6	4360	3200	2760	2380	3470	2540	3500	2710	3420	2240	2640	2410	3360	3060	3640	2590	3320	2610	2720	1990	3360	4150	2790	3730	2620	2200	3230	2090	2850	3300	2180	2030	2940	4360	1990	2370
Government, State and Municipal	19	3930	2770	2720	1880	3100	2470	3280	2250	2940	2060	2480	2450	2970	2500	3220	2380	3170	2240	2430	1730	3400	3670	2360	3540	2350	2070	2990	1710	2630	2710	2120	1990	2640	3930	1710	2220
Portland Cement Manufacturers	13	4410	3020	3100	1900	3490	2760	3680	2640	3230	2180	2650	2550	3460	2830	3400	2570	3320	2410	2670	1860	3730	3890	2630	3630	2540	2140	3140	1680	2960	2820	2260	2120	2860	4410	1680	2730
Railroad	1	3060	2650	2110	1940	2230	1600	3120	2210	2800	1300	2170	1810	2160	2310	3000	2170	3340	1890	2100	1550	3170	2450	1960	3090	1790	1510	2190	1550	1700	2230	1530	1480	2190	3340	1300	2040
University and College	8	3820	2560	2700	1880	3090	2520	3200	2230	2900	2100	2530	2250	2940	2420	3010	2280	3010	2320	2480	1720	3300	3770	2500	3340	2320	1950	2890	1660	2510	2630	2100	2020	2590	3770	1650	2120
Weighted average	47	4080	2860	2810	1950	3230	2550	3400	2410	3070	2100	2540	2430	3140	2640	3280	2440	3200	2340	2540	1790	3500	3780	2500	3540	2420	2070	3030	1740	2640	2790	2150	2030	2720	4020	1730	2290
28-Day Tests																																					
Commercial	6	6550	4780	5560	4440	5650	5220	6230	4950	5250	5120	5190	4130	6350	6110	6500	4730	6350	5250	5730	3870	5540	6560	4740	5310	5250	4750	4920	4470	4670	5420	4020	3970	5240	6560	3870	2690
Government, State and Municipal	19	7300	4940	5740	3810	5910	5450	6060	5400	5330	4920	5050	4160	6220	6200	6800	5190	6750	5760	5480	3690	5940	6700	5090	5730	4990	4320	4940	3930	4440	5230	4240	4230	5290	7300	3690	3610
Portland Cement Manufacturers	13	7450	5050	5820	3780	5760	5540	6600	5550	5790	4920	5200	4250	6780	6100	6680	5360	7290	5610	5700	3830	6440	7000	5000	5620	5150	4410	5290	4150	4750	5460	4040	4180	5450	7450	3780	3670
Railroad	1	7050	4670	4900	3500	4780	3730	5330	4550	5000	3490	5150	3020	4430	3520	5500	2500	3820	3580	4080	2560	4090	3600	3380	4360	2570	3190	3260	3800	3500	4150	3570	3020	3980	7050	2500	4550
University and College	8	6910	4830	5760	3940	5480	5420	6040	5060	5000	4880	4810	3900	6100	5590	6570	4430	6130	5340	5240	3390	5500	6310	4170	5450	4780	4100	4840	3610	4230	4050	3710	4230	5040	6910	3390	3520
Weighted average	47	7160	4920	5720	3900	5730	5400	6200	5300	5380	4900	5070	4110	6330	6000	6660	5000	6680	5540	5500	3680	5910	6630	4820	5560	4980	4330	4980	4000	4490	5100	4050	4150	5230	7160	3680	3480
3-Month Tests																																					
Commercial	6	7780	7460	7700	6060	6970	6780	7180	7080	6710	6660	6490	6160	7610	7720	7720	6900	7700	6790	6920	6250	6940	7140	7090	7050	7280	7290	6950	6690	6420	7160	6230	6850	6990	8260	6050	2250
Government, State and Municipal	19	8300	6990	7860	5860	7500	7420	7120	6900	6510	6880	7000	6210	8050	7990	8180	6850	8390	7270	7560	6660	7100	7500	7220	6870	7160	7280	6360	7000	6930	6850	6700	6780	7160	8390	5860	2330
Portlent Cement Manufacturers	13	8350	7220	8160	5900	7340	7520	7480	7090	6700	6860	6800	6290	8430	8010	8270	6840	8260	7160	7180	6660	7190	8250	6970	6700	7030	6940	6320	6740	6800	6750	6210	6800	7150	8430	5900	2530
Railroad	1	7790	7090	7500	5420	6520	6370	5880	6500	6230	5500	7060	5350	6050	5780	7260	5500	6970	6100	6500	4990	4690	5520	6070	4740	6290	6960	5480	7050	5520	4310	4930	5830	6050	7790	4310	3480
University and College	8	8290	7100	7950	6230	6800	7450	7070	7100	6550	6830	6790	6110	7950	8140	8320	6480	7880	7010	7590	6570	7080	8200	7310	6500	6970	6900	6310	6430	6580	6280	6330	6720	7060	8320	6110	2210
Weighted average	47	8250	7150	7940	5940	7250	7360	7200	7000	6590	6810	6860	6180	8050	7950	8150	6770	8140	7110	7860	6550	7050	7740	7130	6760	7100	7110	6400	6790	6750	6730	6400	6770	7100	8290	5940	2350

Note.—The values given in boldface figures are the high and low values of the weighted averages and are not the average of the high and low values for the individual groups.

(*b*) Average Mean Variations in Compressive Strengths of the 3 Neat Cement Compression Specimens from a batch for each group of Laboratories.

Laboratory	Number Reporting	Cements 1–32																																Average Value	High Value	Low Value	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32				
3-Day Tests																																					
Commercial	6	5.8	5.4	3.0	4.3	3.8	3.1	4.8	1.9	4.0	5.2	2.2	2.7	4.6	2.7	3.5	3.3	4.8	2.9	4.1	5.3	3.4	2.9	3.0	3.9	3.7	3.0	4.6	4.6	3.1	5.6	4.5	4.9	3.9	5.8	1.9	....
Government, State and Municipal	19	3.6	3.7	3.0	4.4	3.5	4.6	4.3	3.9	4.4	4.7	3.3	4.6	4.4	4.0	4.0	4.1	2.8	3.2	4.2	3.6	3.2	3.7	3.1	4.0	4.1	5.9	5.2	3.7	4.3	4.6	3.8	3.3	4.0	5.9	2.8	....
Portland Cement Manufacturers	13	4.5	2.4	4.3	2.9	2.5	4.6	2.5	2.0	3.8	3.1	3.7	2.5	3.0	3.0	3.0	3.1	2.6	3.7	3.5	3.0	2.8	2.4	1.8	3.8	3.1	3.6	2.2	2.5	3.3	3.6	4.0	3.3	3.1	4.6	2.0	....
Railroad	1	7.2	2.3	3.7	1.1	5.0	1.3	4.2	4.7	2.6	5.6	6.2	5.3	5.9	3.9	2.5	2.8	3.1	6.7	8.1	5.2	3.3	4.1	7.4	3.4	6.1	5.9	6.7	5.6	4.6	6.7	3.0	1.0	4.5	8.1	1.0	....
University and College	8	4.4	3.1	5.2	3.6	2.6	5.1	3.5	3.1	3.5	5.7	4.3	3.6	3.8	5.6	5.8	2.6	5.3	5.2	3.8	5.0	3.6	5.3	6.2	2.8	5.0	3.6	3.7	4.2	3.3	4.6	2.8	4.3	4.2	6.2	2.6	....
Weighted average	47	4.2	3.6	3.8	3.8	3.1	4.4	3.7	3.0	4.0	4.5	3.5	3.6	4.0	3.8	3.9	3.4	3.4	3.7	4.1	3.9	2.9	3.5	3.3	3.7	3.9	4.5	4.1	3.6	3.7	4.5	3.8	3.6	3.7	**4.5**	**2.9**	....
7-Day Tests																																					
Commercial	6	5.9	6.4	4.6	4.3	3.7	3.1	4.6	2.8	2.2	5.9	4.6	3.6	4.0	2.3	3.5	3.3	3.1	3.2	2.8	4.3	4.0	2.5	7.2	2.5	2.2	3.4	3.1	3.0	3.0	4.0	4.0	4.4	3.8	6.4	2.2	....
Government, State and Municipal	19	5.0	4.4	2.8	2.4	3.9	3.2	3.1	2.9	3.9	4.2	3.4	3.6	3.4	3.5	5.2	2.6	3.3	4.4	3.6	3.8	3.1	4.1	2.9	4.4	3.8	4.9	3.1	4.3	4.1	4.2	3.7	3.5	3.7	5.2	2.6	....
Portland Cement Manufacturers	13	3.5	2.5	2.4	3.0	2.7	3.1	3.0	3.2	2.8	2.4	2.5	3.3	2.2	2.7	3.3	1.9	4.0	2.8	3.1	3.6	3.1	2.2	3.1	1.7	2.2	2.4	3.2	4.3	3.3	2.1	2.8	2.1	2.9	4.3	1.7	....
Railroad	1	4.7	2.4	3.5	2.7	3.9	6.0	1.4	2.3	2.4	4.9	5.5	3.5	2.6	2.3	3.9	4.5	4.7	2.8	3.6	4.7	5.0	9.5	5.1	4.0	4.5	2.0	2.9	3.0	2.9	3.0	4.1	6.5	3.9	9.5	1.4	....
University and College	8	6.4	6.4	5.4	4.2	4.7	6.4	3.8	3.1	3.3	4.9	5.3	5.1	4.8	4.5	3.4	4.4	7.0	3.9	4.5	7.1	4.3	5.4	4.8	4.0	3.4	4.5	3.7	6.0	5.0	2.3	4.1	4.2	4.7	7.1	2.3	....
Weighted average	47	4.9	4.4	3.4	3.2	3.7	3.8	3.4	3.0	3.2	4.1	3.6	3.8	3.4	3.2	4.1	2.8	4.1	3.7	3.5	4.8	3.5	3.7	3.9	3.4	3.1	3.9	3.2	4.4	3.9	3.2	3.6	3.4	3.6	**4.9**	**2.8**	....
28-Day Tests																																					
Commercial	6	4.3	7.3	5.9	7.5	2.6	6.1	6.8	5.2	3.9	2.7	5.6	4.0	5.0	2.5	6.4	6.7	6.2	3.5	4.8	3.8	7.0	3.7	3.5	4.1	4.8	4.1	1.9	3.0	3.4	3.1	4.7	3.7	4.5	7.5	1.9	....
Government, State and Municipal	19	5.6	4.3	4.4	4.3	3.6	6.0	5.2	4.1	4.9	4.8	2.7	3.7	5.1	3.7	4.9	4.9	3.5	3.9	4.9	4.4	5.3	6.4	3.8	4.4	4.8	4.6	4.3	3.7	4.7	3.6	3.9	3.0	4.4	6.4	2.7	....
Portland Cement Manufacturers	13	3.3	4.3	3.6	4.5	2.3	3.0	2.7	3.5	2.9	4.1	2.6	2.9	3.5	4.1	3.0	3.2	3.2	3.5	3.0	3.5	2.5	2.8	2.9	3.8	3.9	3.9	2.7	2.2	2.0	3.5	2.4	2.7	3.2	4.5	2.3	....
Railroad	1	2.4	7.3	2.7	4.9	1.7	5.2	3.3	3.2	2.6	2.4	4.1	0.9	5.3	5.8	2.8	3.2	3.8	2.7	4.5	6.6	4.6	4.7	2.7	2.5	3.9	4.7	1.8	9.6	2.4	2.2	3.8	5.8	3.9	9.6	0.9	....
University and College	8	3.3	4.9	5.3	3.5	7.8	4.8	6.6	4.4	7.1	6.4	5.9	4.3	6.5	6.6	6.2	7.5	6.1	5.6	5.6	7.3	4.7	7.9	5.7	7.6	4.2	4.2	5.5	6.4	6.2	6.1	6.4	3.4	5.8	7.9	3.3	....
Weighted average	47	4.3	4.8	4.5	4.1	3.8	4.9	4.9	4.1	4.5	4.5	3.6	3.6	4.9	4.2	4.8	5.1	4.2	4.0	4.5	4.6	4.6	5.2	3.8	4.7	4.4	4.3	5.0	3.8	4.0	3.9	4.0	3.1	4.3	**5.2**	**3.1**	....
3-Month Tests																																					
Commercial	6	6.1	3.6	4.8	2.9	4.0	3.1	2.6	3.8	4.1	1.6	3.6	3.6	3.9	3.8	3.1	3.5	4.4	4.2	4.2	5.8	4.2	2.9	2.9	2.5	2.2	1.6	2.6	2.1	2.4	5.0	2.7	4.1	3.5	6.1	1.6	....
Government, State and Municipal	19	6.2	5.8	4.6	5.4	4.1	6.5	5.2	5.8	4.4	5.4	4.5	5.8	4.3	6.1	7.2	3.3	6.7	5.9	6.9	5.5	5.8	7.6	5.2	5.5	4.3	4.7	5.4	5.1	3.5	5.6	4.1	4.5	5.3	7.6	3.5	....
Portland Cement Manufacturers	13	5.0	5.2	3.5	5.3	4.6	4.4	4.0	4.3	3.9	6.0	3.4	4.7	4.7	4.7	5.1	4.1	3.6	4.3	2.2	2.5	3.3	3.6	3.6	3.6	5.0	3.6	3.9	3.2	2.9	4.7	4.0	3.0	4.1	6.0	2.2	....
Railroad	1	7.5	10.8	5.5	10.9	6.2	14.0	20.6	10.0	6.8	16.2	2.8	9.8	12.8	11.4	8.3	16.3	16.3	11.0	3.4	18.6	7.5	15.7	1.6	16.8	10.3	2.4	11.6	7.9	7.1	10.7	6.4	4.8	10.1	20.6	1.6	....
University and College	8	7.3	4.7	5.2	3.9	6.5	3.7	8.9	5.2	8.9	4.7	4.4	6.9	5.1	5.2	7.3	6.6	6.1	6.7	8.0	6.2	8.3	5.2	5.4	7.0	6.8	3.6	5.2	6.6	6.6	6.1	4.3	3.0	5.9	8.9	3.0	....
Weighted average	47	6.1	5.3	4.5	4.9	4.7	5.1	5.5	5.1	5.0	5.2	4.1	5.4	4.7	5.4	6.1	4.4	5.7	5.5	5.4	5.1	5.4	5.7	4.4	5.1	4.8	3.8	4.8	4.5	3.8	5.5	4.0	3.8	5.0	**6.1**	**3.8**	....

Note.—The values given in boldface figures are the high and low values of the weighted averages and are not the average of the high and low values for the individual groups.

under damp cloths until tested; care shall be taken to see that the sand or cloth shall not fall outside the range of 65 to 75° F.

Testing.—Cylinders shall be tested damp, using a spherical bearing block carefully centered on top. The load shall be applied uniformly and without shock. The moving head of the testing machine should travel at a rate of about 0.05 in. per minute when the machine is running idle.

DATA OF TESTS

The 47 cooperating laboratories submitted partial or complete data of miscellaneous and strength tests on the cements. In addition, 7 of these laboratories submitted data of 7 and 28-day tests of 6 by 12-in. concrete cylinders; the data of concrete tests from one laboratory were received too late for inclusion in this report. Table III gives the results of concrete tests by 6 laboratories. Sieve analyses and miscellaneous tests of the aggregates used in the concrete tests are given in Table VIII.

In the cement tests, the individual and average strengths of the 3 specimens from a batch were reported. The averages of the individual strengths were checked, and mean variations of the individual strengths from their average calculated and checked and the values tabulated for each laboratory and type of specimen for ages of test of 3, 7 and 28 days and 3 months. On account of the great number and size of the tables giving the detailed data of the strength tests on the neat cement and 1:3 mortar specimens they have been omitted from this report. The average strengths of the tension and compression specimens and the average mean variations of the 3 specimens from a batch are summarized in Tables IV, V and VI for each of the five groups of laboratories.

Data of the miscellaneous tests on the cements are given in the reports of Sub-Committees I, III, V and VI.

Table VII gives the mean variations of the strengths obtained by each laboratory from the grand average strength for each cement and type of specimen. Table IX gives the type and capacity of testing machines used by the various laboratories in testing the strength specimens; it also gives the method employed in obtaining the required thumb pressure in molding the 1:3 standard sand briquets. Table X gives data of temperature and relative humidity. Table XI summarizes comparisons of the results obtained by the various laboratories with the requirements of the A.S.T.M. Standard Specifications and Tests for Portland Cement (C 9 – 26).

Certain discrepancies in the data submitted were noted, but for the purpose of this report, omission of test data have been made only in a few cases where the results were obviously in error. Some of the more significant relations for the strength tests of the cements and the concrete are shown graphically in Figs. 1 to 10.

DISCUSSION OF TESTS

Uniformity of Strengths of 3 Specimens from a Batch.—In this investigation, 1:3 standard sand briquets and neat cement tension and compression specimens were made in sets of 3 from a single batch for test at a given age. One of the objects of the investigation was to obtain a comparison of the uniformity of the strengths of the 3 specimens from a batch for each type of specimen. The following tabulation of the average mean variations for the 32 cements for each of the five groups of laboratories from Tables IV to VI gives a comparison of the uniformity of the strengths obtained with the different types of specimen:

Laboratory	Average Mean Variation of the 3 Specimens from a Batch for 32 Cements, per cent				Spread[a]			
	3 days	7 days	28 days	3 months	3 days	7 days	28 days	3 months
COMPRESSION TESTS OF NEAT CEMENT 2-IN. CUBES OR 2 BY 4-IN. CYLINDERS								
Commercial (6)	3.9	3.8	4.5	3.5	3.9	4.2	5.6	4.5
Government, State, etc. (19)	4.0	3.7	4.4	5.3	3.1	2.6	3.7	4.3
Portland Cement Mfr. (13)	3.1	2.9	3.2	4.1	2.6	2.6	2.2	3.8
Railroad (1)	4.5	3.9	3.9	10.1	7.1	8.1	8.7	19.0
University and College (8)	4.2	4.7	5.8	5.9	3.6	4.8	4.6	5.9
Weighted Average for all Laboratories (47)	3.7	3.6	4.3	5.0	1.4	2.1	2.1	2.3
TENSION TESTS OF NEAT CEMENT BRIQUETS								
Commercial (6)	3.9	3.7	3.2	3.6	6.2	3.0	4.4	4.2
Government, State, etc. (19)	4.6	4.4	4.2	5.1	3.0	3.3	2.7	2.9
Portland Cement Mfr. (13)	4.0	3.7	3.7	4.1	2.9	2.2	2.6	1.9
Railroad (1)	5.5	4.3	3.6	3.8	11.4	10.2	6.1	5.5
University and College (8)	5.5	5.0	5.1	5.8	6.6	3.8	4.1	5.1
Weighted Average for all Laboratories (47)	4.5	4.2	4.2	4.7	1.9	1.6	1.4	1.9
TENSION TESTS OF 1:3 STANDARD SAND BRIQUETS								
Commercial (6)	3.2	3.0	2.5	2.6	4.9	3.5	2.4	3.4
Government, State, etc. (19)	4.4	4.2	3.4	3.8	2.6	2.8	2.2	2.5
Portland Cement Mfr. (13)	3.9	3.6	3.1	3.2	2.3	2.0	2.0	2.5
Railroad (1)	5.1	4.1	3.9	3.9	9.1	9.0	9.6	6.8
University and College (8)	4.9	4.4	4.1	4.2	3.1	5.9	3.8	4.0
Weighted Average for all Laboratories (47)	4.2	3.9	3.3	3.6	1.8	1.5	1.3	1.5
COMPRESSION TESTS OF 6 BY 12-IN. CONCRETE CYLINDERS								
2 Laboratories	6.6	...	...	...	11.0	...	...	...
6 Laboratories	...	5.3	5.4	...	...	6.6	4.5	...

[a] Spread is the difference between the high and low mean variations for the 32 cements for a given group of laboratories.

So far as the uniformity in strength of the 3 specimens from a batch is concerned, the compression tests of neat cement gave more concordant results than either the tension tests of neat cement or 1:3 standard sand briquets at 3 and 7 days and somewhat less concordant results than the briquet tests at 28 days and 3 months. The higher mean variations in the 28-day and 3-months neat cement compression tests were due in part to the fact that a few laboratories obtained erratic results with some of the cements at these ages; in some cases the individual laboratories had average mean variations two times the grand average, the mean variations for individual cements being as high as 33 per cent. The laboratories which had erratic compression tests generally used 2 by 4-in. cylinders for test specimens and the erratic results may have been due to faulty capping.

TABLE VII.—MEAN VARIATIONS OF THE STRENGTHS OBTAINED BY EACH LABORATORY FROM THE GRAND AVERAGE STRENGTH.

Cement	Mean Variations, per cent											
	3 Days			7 Days			28 Days			3 Months		
	1:3 Standard Briquet	Neat Briquet	Neat Compression Test	1:3 Standard Briquet	Neat Briquet	Neat Compression Test	1:3 Standard Briquet	Neat Briquet	Neat Compression Test	1:3 Standard Briquet	Neat Briquet	Neat Compression Test
No. 1	8.6	10.6	15.1	7.9	8.5	15.1	6.5	8.5	13.7	6.8	9.5	12.8
No. 2	12.0	12.5	13.4	9.0	9.9	12.3	6.5	8.2	9.5	5.9	8.6	8.2
No. 3	9.7	12.0	14.1	9.7	8.6	13.7	7.4	10.8	14.4	6.0	10.0	11.0
No. 4	13.1	15.8	15.0	10.7	11.2	13.7	7.5	9.4	10.1	7.3	9.8	9.9
No. 5	8.8	11.9	12.9	8.4	11.4	15.1	7.7	9.6	12.8	8.0	10.0	11.3
No. 6	8.9	12.6	13.1	8.9	10.1	11.9	7.4	9.9	13.9	6.8	10.3	12.3
No. 7	10.6	14.6	18.6	8.9	11.5	17.7	8.3	10.6	12.8	7.5	9.3	12.7
No. 8	11.6	13.1	16.4	9.9	13.7	16.0	7.6	9.8	13.2	5.8	11.7	12.3
No. 9	12.5	13.6	18.6	9.6	11.3	17.1	6.9	10.4	13.7	7.0	9.4	13.5
No. 10	12.5	13.9	17.0	8.6	11.6	13.3	7.7	10.6	13.9	6.3	10.4	12.7
No. 11	11.0	12.7	14.8	8.5	12.1	11.6	7.7	10.8	10.4	7.0	9.5	9.6
No. 12	9.2	12.8	14.0	9.4	10.0	13.2	8.5	9.0	10.1	7.7	8.1	11.4
No. 13	9.6	11.6	19.5	9.1	9.4	16.3	9.2	8.7	13.2	7.8	9.2	12.5
No. 14	10.9	12.8	13.5	8.3	10.3	13.4	9.0	9.5	12.8	6.9	9.7	13.2
No. 15	11.6	14.5	17.0	9.5	9.0	17.6	8.6	10.2	13.2	7.0	10.5	14.2
No. 16	10.9	13.5	15.0	8.5	9.5	13.8	7.1	8.3	14.9	6.8	7.0	13.9
No. 17	10.9	13.7	17.3	8.7	11.1	15.1	8.8	10.7	13.4	8.0	8.8	14.6
No. 18	12.8	15.3	17.1	10.4	10.7	16.3	9.1	8.2	16.2	7.6	9.8	12.2
No. 19	10.7	13.9	13.1	10.2	10.5	12.4	8.6	9.4	11.9	7.2	8.3	11.4
No. 20	14.1	11.4	13.5	11.2	8.7	8.6	8.6	7.9	9.0	7.0	8.9	10.7
No. 21	9.7	11.0	14.8	8.6	9.4	15.3	8.0	8.9	13.0	7.2	9.8	15.2
No. 22	9.6	11.4	12.4	6.5	8.7	12.6	6.9	8.2	14.3	5.6	9.2	15.7
No. 23	11.6	12.2	14.1	9.5	9.4	13.9	8.0	9.4	12.7	7.0	12.0	12.0
No. 24	10.3	14.1	17.7	8.7	11.6	15.9	7.4	9.0	15.0	7.3	9.0	12.7
No. 25	8.8	10.4	12.6	10.6	9.8	12.7	8.6	7.9	13.7	7.0	7.5	13.7
No. 26	16.0	18.1	17.1	9.8	12.3	14.1	9.2	10.0	14.3	7.4	8.9	13.2
No. 27	10.9	13.9	13.6	8.2	10.3	13.1	7.9	8.6	13.4	7.9	10.0	13.8
No. 28	14.9	18.0	18.5	12.1	13.1	14.4	7.7	8.5	12.8	7.3	9.0	13.7
No. 29	11.0	10.9	13.7	9.6	10.3	11.3	6.0	8.9	9.7	7.1	8.8	10.1
No. 30	12.3	13.7	14.4	9.4	11.7	16.6	8.6	9.6	16.3	7.1	9.1	12.6
No. 31	12.1	9.4	13.3	11.0	9.7	11.1	8.2	7.5	11.0	7.7	7.2	9.3
No. 32	12.2	11.9	12.3	11.1	11.0	13.2	8.3	8.7	12.6	7.7	8.4	9.9
Average	11.2	13.1	15.1	9.4	10.5	14.0	7.9	9.2	12.9	7.1	9.3	12.3
High	14.9	18.1	19.5	12.1	13.7	17.7	9.2	10.8	16.3	8.0	11.7	15.7
Low	8.6	9.4	12.3	6.5	8.5	8.6	6.0	7.5	9.0	5.6	7.0	8.2

The tension tests of 1:3 standard sand briquets showed somewhat greater uniformity than the tension tests of neat cement briquets, particularly at 28 days and 3 months.

The mean variations for each of the three types of specimens were outstandingly lower for two or three of the laboratories than for the others. The agreement in strength for any three specimens broken at the same time, obtained by these very few laboratories, is far better than that obtained in the majority of cases by the majority of laboratories. Considerable interest has been aroused as to how this has been accomplished.

The "spread," that is, the difference between the high and low values of the mean variations for 32 cements for a given group of laboratories, was about the same for the tension tests of the neat cement and 1:3 briquets, the values for these two types of specimen being somewhat less than for the neat cement cubes.

Uniformity of Strengths as Between Laboratories.—Large differences were found in the strengths obtained by the individual laboratories with the 3 types of specimens. The differences between the average of the high and low strengths reported for the 32 cements by individual laboratories ranged from about 75 to 85 per cent of the grand average strength at 3 days to 50 to 65 per cent at 3 months. In individual cases, the differences between the high and low strengths were as much as 139 per cent of the grand average strength in the 3-day tests and as much as 100 per cent in the 3-months tests. One laboratory reported strengths of 1:3 standard sand briquets about 100 lb. per sq. in. higher at all ages of test than the grand average and another laboratory reported 1:3 mortar briquet strengths which were from about 50 to 100 lb. per sq. in. below the grand average strengths.

Table VII summarizes the mean variations in the strengths obtained by the individual laboratories from the grand average strength for all laboratories for each cement and type of specimen at 3, 7 and 28 days and 3 months. The averages of the mean variations for the 32 cements for each type of specimen were as follows:

Type of Specimen	Method of Loading	Average Mean Variation, per cent			
		3 days	7 days	28 days	3 months
1:3 Standard Sand Briquets (46 Laboratories)	Tension	11.2	9.4	7.9	7.1
Neat Briquets (47 Laboratories)	Tension	13.1	10.5	9.2	9.3
Neat 2-in. Cubes or 2 by 4-in. Cylinders (47 Laboratories)	Compression	15.1	14.0	12.9	12.3

The mean variations obtained in the tension tests of the 1:3 mortar briquets were much lower than the variations in the compression tests of the neat cement cubes or cylinders. The mean variations in the neat cement briquet strengths were not greatly different from those of the 1:3 standard sand briquets, which seems logical since the type of specimen was the same in each case and the specimens were tested on the same machines. In the tests of the neat cement compression specimens, however, a variety of types and capacities of testing machines were used as may be seen from Table IX, which, no doubt, was partly responsible for the higher variations found in the compression tests. Furthermore, other factors such as rate of application of load, size of bearing block and trueness of bearing surfaces, condition of the caps in the case of the 2 by 4-in. cylinders or of the bearing surfaces in the case of the 2-in. cubes may have exerted a marked influence on the results.

TABLE VIII.—SIEVE ANALYSES AND MISCELLANEOUS TESTS OF AGGREGATES.

Sieve Size	Size of Square Opening, in.	Laboratory 35		Laboratory 16		Laboratory 20		Laboratory 30		Laboratory 43		Laboratory 44	
		Sand	Gravel	Sand	Gravel	Sand	Gravel	Sand	Gravel	Sand	Gravel	Sand	Gravel
SIEVE ANALYSIS													
No. 100...	0.0058	99	100	95	100	95	100	98	100	95	99	96	100
No. 48...	0.0117	90	100	81	100	77	100	87	100	88	99	90	100
No. 28...	0.0232	59	100	47	100	40	100	50	100	65	98	74	100
No. 14...	0.046	38	100	30	100	27[a]	100	27	100	45	97	50	100
No. 8...	0.093	17	100	18	100	15[a]	100	14	100	24	97	25	100
No. 4...	0.185	0	100	4	100	3	100	4	98	4	92	4	97
$\frac{3}{8}$ in......	0.37	..	70	0	60	0	95[b]	0	93	0	60	0	78
$\frac{3}{4}$ in......	0.75	..	30	..	20	..	63[b]	..	66	..	30	..	34
$1\frac{1}{2}$ in.....	1.5	..	0	..	0	..	0	..	0	..	0	..	0
Fineness Modulus		3.03	7.00	2.75	6.80	2.57		2.80	7.47	3.21	6.72	3.39	7.09
MISCELLANEOUS TESTS													
Silt, per cent by weight..........		1.3	washed	2.2	washed	0.8	....	1.6	....	5.5	1.0	....	....
Absorption, per cent by weight after $\frac{1}{2}$ hour..........		1.0	1.0	1.8	1.0	....	0.14	1.0	0.28	4.0	0.6	0.1	0.9
Specific Gravity...		2.65	2.65	2.52	2.57	2.64	2.78	2.65	2.81	2.63	2.58	2.66	2.67
Weight, lb. per cu. ft.		114	108 (128)[c]	105	108 (126)[c]	113	100 (130)[c]	104	104 (128)[c]	107.5	112.0 (120)[c]	114	102 (128)[c]
Organic Impurities.		OK	...	OK	...	OK	...	OK	...	OK	...	OK	...

[a] No. 20 and No. 10 sieves used; percentages obtained by interpolation in this case.
[b] Sieves with round openings used for coarse aggregate.
[c] Values in parentheses are weight per cubic foot of mixed aggregate.

In these studies no distinction was made between compression tests of neat cement cubes and 2 by 4-in. cylinders. In order to obtain

TABLE IX.—NOTES ON TESTING MACHINES AND ON MEASUREMENT OF PRESSURE IN MOLDING BRIQUETS.

Laboratory	Method of Measuring Pressure in Molding 1:3 Briquets	Machines Used in Testing			
		Briquets		2-in. Cubes or 2 by 4-in. Cylinders	
		Capacity, lb.	Type	Capacity, lb.	Type
(A) COMMERCIAL TESTING LABORATORIES (8)					
No. 1	Delimeter	1000	Olsen-Boyd	150 000	Universal
No. 2		....	Olsen-Boyd	100 000	Olsen
No. 3	Depended on experience of operator	1000	Shot	100 000	Universal
No. 4	Platform scale	....	Fairbanks	50 000[a]	Olsen
No. 5	In accordance with A.S.T.M. Specifications	1000		200 000[b]	
No. 6	Checked on platform scale	2000	Olsen-Boyd	250 000[c]	
No. 7		1000	Riehle	50 000	Riehle
No. 8		....	Fairbanks	......	Olsen
(B) GOVERNMENT, STATE AND MUNICIPAL (19)					
No. 9	Checked on scale	1000	Fairbanks	200 000	Riehle
No. 10	Checked on platform scale	2000	Olsen	40 000	Olsen
No. 11	Depended on experience of operator	....		......	
No. 12	Checked on platform scale	1000		200 000	
No. 13	Delimeter	1000	Olsen	100 000	Riehle Universal
No. 14	Platform scale	2000	Shot	50 000	Universal
No. 15		....	Olsen	50 000	Olsen
No. 16	Based on delimeter trials (20 lb.)	....	Fairbanks	20 000 50 000	3-screw 2-screw
No. 17	Delimeter (25 to 30 lb.)	1000	Olsen	50 000	Riehle
No. 18		....	Riehle	300 000	Olsen
No. 19	Pressure checked occasionally	....	Fairbanks	......	Riehle screw
No. 20	Delimeter	1000	Olsen	20 000	Olsen
No. 21		....	Olsen-Boyd	30 000	Olsen Transverse
No. 22	Platform scale	1000	Olsen	150 000	Riehle
No. 23	Platform scale	1000	Olsen-Boyd	200 000	Riehle Universal
No. 24	Checked on platform scale	1000	Fairbanks	50 000	Olsen
No. 25	Delimeter	1000	Riehle	40 000	Olsen
No. 26	Platform scale (17½ lb.)	1000	Olsen-Boyd	50 000	Olsen
No. 27	Depended on experience of operator[d]	1000	Riehle	100 000	Riehle
(C) PORTLAND CEMENT MANUFACTURERS (13)					
No. 28	Delimeter	2000	Fairbanks	30 000	Riehle
No. 29	Checked on platform scale	1000	Olsen-Boyd	28 000	Pittsburgh Testing Laboratory
No. 30	Checked on delimeter	1000		50 000	
No. 31	Checked on delimeter	....	Riehle	......	Riehle
No. 32	Depended on experience of operator	1000	Olsen Automatic	200 000	Riehle
No. 33	Delimeter	....	Olsen Automatic	......	Riehle
No. 34	Checked on platform scale	1000	Olsen Automatic	200 000	Riehle
No. 35	Checked on platform scale	1000	Olsen Automatic	50 000	Riehle
No. 36	Delimeter	2000	Fairbanks	300 000	Olsen
No. 37	Checked on Fairbanks scale	1000	Riehle	......	Hydraulic Pittsburgh Testing Laboratory
No. 38	Platform scale (17½ lb.)	1000	Olsen-Boyd	200 000	Olsen Hydraulic
No. 39	Checked on platform scale	1000	Olsen	50 000	Riehle
No. 40	Delimeter	1000	Shot	25 000	Hydraulic
(D) RAILROAD (2)					
No. 41		1000	Fairbanks	20 000	Built by this railroad
No. 42		....		......	

[a] Also 25,000-lb. P. T. L.; [b] Also 50,000-lb.; [c] Also 20,000-lb.; [d] Half-filled mold thumbed 12 times; filled mold thumbed 12 times; then trowelled.

TABLE IX.—NOTES ON TESTING MACHINES AND ON MEASUREMENT OF PRESSURE IN MOLDING BRIQUETS.—*Continued.*

Laboratory	Method of Measuring Pressure in Molding 1:3 Briquets	Machines Used in Testing			
		Briquets		2-in. Cubes or 2 by 4-in. Cylinders	
		Capacity, lb.	Type	Capacity, lb.	Type
	(E) UNIVERSITY AND COLLEGE (10)				
No. 43	Checked on sensitive scales	1000	Olsen Shot	50 000	Riehle
No. 44	Platform scale	1000	Riehle	50 000	Riehle
No. 45	Depended on experience of operator	....	Olsen	150 000	Riehle
No. 46	....	....	....	......	
No. 47	Checked on platform scale	1000	....	50 000	
No. 48	Checked on platform scale	2000	Riehle Lever	30 000	Lever type
No. 49	Delimeter	1000	....	50 000	
No. 50	....	....	....	......	
No. 51	Toledo automatic scales	1000	Olsen-Boyd	30 000[e]	Olsen
No. 52	Depended on experience of operator	2000	Riehle lever hand-operated	30 000	Olsen Universal

[e] 50,000 lb. for 3-month tests.

information on the strengths of the 2-in. cubes as compared with the 2 by 4-in. cylinders separate studies were made of the data, the results of which are summarized in the following tabulation:

Type of Neat Cement Specimen	Average Compressive Strength, lb. per sq. in.				Average Mean Variations, per cent							
					In Strengths of the 3 Specimens from a Batch				In Strengths Reported by Individual Laboratories			
	3 days	7 days	28 days	3 mos.	3 days	7 days	28 days	3 mos.	3 days	7 days	28 days	3 mos.
2-in. Cubes (21 Laboratories)	1660	2860	5500	7410	3.3	3.4	3.9	4.1	12.9	11.9	10.6	....
2 by 4-in. Cylinders (26 Laboratories)	1540	2600	5050	6830	4.1	3.8	4.6	5.6	16.2	15.0	13.9	....

The above data show that the 2-in. cubes gave about 10 per cent higher strengths and lower mean variations than the 2 by 4-in. cylinders at all ages. The results of compression tests on 2-in. cubes and 2 by 4-in. cylinders of neat cement from other investigations showed little, if any, difference in the average strengths or mean variations at 3, 7 and 28 days for the two types of specimen.

Concrete Tests.—Data of concrete tests by 6 laboratories are given in Table III. In considering these data, it should be borne in mind that the laboratories used local aggregates and a few of them reported difficulty in obtaining plastic mixes with the quantities of material specified.

There was considerable difference in the concrete strengths reported by the 6 laboratories. The average of the differences between the high and low strengths reported for the 32 cements by individual laboratories was 690 lb. per sq. in. at 7 days and 1410 lb. per sq. in. at 28 days. These values are 37 and 45 per cent of the grand average strengths at 7 and 28 days which were 1850 and 3120 lb. per sq. in., respectively. The laboratory which generally obtained the highest results reported strengths about 40 per cent in excess of those obtained by the laboratories reporting the lowest results.

The results of the concrete tests were studied in detail by plotting curves with the 32 cements arranged in the order of ascending grand average strengths at 7 and 28 days and then superimposing on these curves the strengths obtained by each laboratory multiplied by the ratio of its average strength for the 32 cements to the grand average strength for the 6 laboratories. When the data were studied on this basis it was found that the results of the concrete tests by the 6 laboratories were in general quite concordant, showing that by applying to the results of each of the laboratories what might be termed a "laboratory factor," the strengths could be compensated for differences in aggregates, manipulation, curing, etc.

The average mean variations in the strengths of the three 6 by 12-in. concrete cylinders in a set made on 3 different days, were 5.3 per cent at 7 days and 5.4 per cent at 28 days. These values are slightly higher than the mean variations found for the neat cement compression specimens and tension briquets and the 1:3 mortar briquets which, it will be recalled, were made 3 from a batch on the same day.

The average mean variations in the 7 and 28-day concrete strengths obtained by the individual laboratories from the grand average strength for the 6 laboratories were 11.4 per cent and 12.9 per cent, respectively. These values are about the same as the variations of 14.0 and 12.9 per cent obtained in the neat cement compressive strengths and were appreciably higher than the values of 9.4 and 7.9 per cent obtained in the 1:3 briquet strengths from 47 laboratories.

Comparison of Neat Cement, 1:3 Mortar and Concrete Tests by Six Laboratories.—Figures 1 to 3 show relations between the strength of neat cement compression specimens, neat cement briquets, and 1:3 standard sand briquets at 3, 7 and 28 days, and the corresponding concrete strengths based on the average strengths from the 6 laboratories (2 laboratories in the case of the 3-day tests) which made both cement and concrete tests.

If there were well-defined relationships between tensile strength

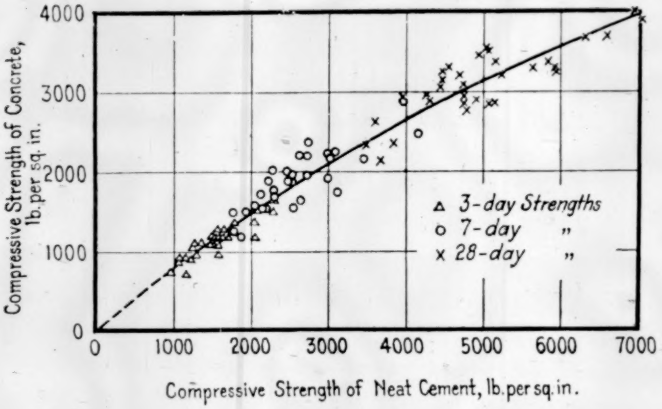

FIG. 1.—Relation of Compressive Strength of Concrete to Compressive Strength of Neat Cement.

Compression tests of 2-in. cubes or 2 by 4-in. cylinders of neat cement mixed **with 42** per cent of water by weight.

Compression tests of 6 by 12-in. concrete cylinders.

Concrete mix, 1:2.4:3.6 by weight. Nominal water-cement ratio 0.90.

Plotted values based on average of tests by six laboratories.

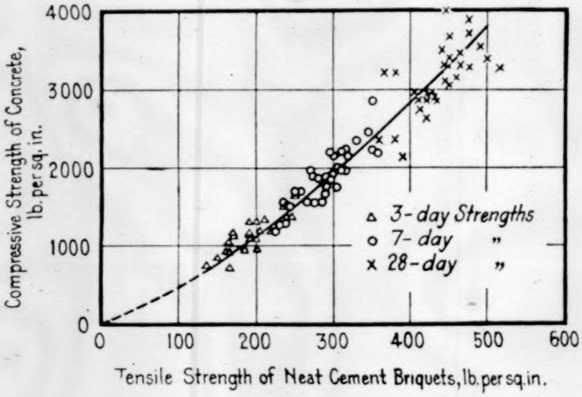

FIG. 2.—Relation of Compressive Strength of Concrete to Tensile Strength of Neat Cement Briquets.

Tension tests of briquets of neat cement mixed with 42 per cent of water by weight.

Compression tests of 6 by 12-in. concrete cylinders. Concrete mix, 1:2.4:3.6 by weight. Nominal water-cement ratio 0.90.

Plotted values based on average of tests by six laboratories.

of 1:3 and neat cement briquets or compressive strength of neat cement and concrete strength, the plotted points in these 3 diagrams would fall on or near the average curves. It will be noted that many of the plotted points deviate appreciably from the average curves, due probably to differences in type of specimen and in the properties of the cements as well as to differences in the tests. The neat cement and 1:3 mortar briquet strengths showed a somewhat greater spread from the average curve at the later ages than the neat compression strengths.

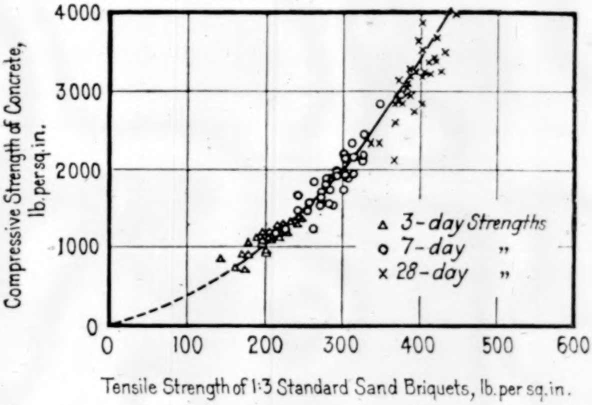

FIG. 3.—Relation of Compressive Strength of Concrete to Tensile Strength of 1:3 Standard Sand Mortar.

Tension tests of briquets of 1:3 standard sand mortar of A.S.T.M. normal consistency.
Compression tests of 6 by 12-in. concrete cylinders. Concrete mix, 1:2.4:3.6 by weight. Nominal water-cement ratio 0.90.
Plotted values based on average of tests by six laboratories.

Figures 7 and 8 show data of neat cement and 1:3 mortar briquets, neat cement compression specimens and concrete cylinders compared on the basis of ascending concrete strengths at 7 and 28 days. These diagrams, as well as Figs. 1 to 3 and Fig. 9, were plotted to see if there was any consistent relationship between the strength of the briquets, cubes or 2 by 4-in. cylinders and the corresponding concrete strengths of the various cements.

There is fair agreement between the strengths of the 3 types of specimen and the concrete strengths at 7 days, but numerous inconsistencies are apparent in the 28-day tests. Differences in the characteristics of the cements as well as variations in the making, curing and testing of the specimens may account for many of the discrepancies in the results and further studies are necessary in order to discover the reasons for these discrepancies.

Figure 9 shows the relation between age at test and the ratio of the strength of a given cement to the average strengths of the 32 cements for neat cement, 1:3 mortar and concrete specimens. Three separate studies were made of these results to see which method of testing the cements gave the best indication of the concrete strength at the various ages.

First, the curves were arbitrarily rated 1, 2, or 3, according to their relative distance from the concrete curve; the curve closest to the concrete curve at all ages was rated 1 and the farthest curve 3. In this comparison, the 1:3 briquets showed a rating of 1.8 against 2.0 for the neat briquets and 2.2 for the neat compression specimens, the lower rating indicating the smaller deviation from the concrete curve. On this basis the 1:3 briquet was the most satisfactory type of specimen for indicating concrete strength.

In the second method of comparison, the individual curves were rated according to their position relative to the concrete curve, the most extreme curve for all the cements being given a rating of 10 and the other points rated according to their proportionate distance from the concrete curve. On this basis both the neat compression specimens and the 1:3 briquets had a rating of 2.80, while the neat briquets had a rating of 2.95, the neat briquets showing slightly less favorably than the other two types of specimen.

In the third method of comparison, a study was made of the differences between the strength ratios for the concrete tests and those for each of the other types of specimen expressed as plus or minus deviations from the concrete strength ratios. The averages of these differences for the various cements were as follows:

Age at Test	Average Deviations from Concrete Strength Ratios					
	Standard Sand Briquets		Neat Cement Briquets		Neat Cement Compression Specimens	
3 days	+ 8.1	−8.4	+ 8.6	−9.6	+6.4	−10.4
7 days	+11.1	−7.9	+11.2	−9.2	+7.3	−10.1
28 days	+ 8.6	−6.3	+ 9.2	−6.3	+8.6	− 7.4
Grand Average	+ 9.3	−7.2	+ 9.7	−8.4	+7.4	− 9.3

On this basis, if the agreement were exact the above differences would be zero. The type of specimen which gives the lowest deviations and deviations which are most harmonious with reference to

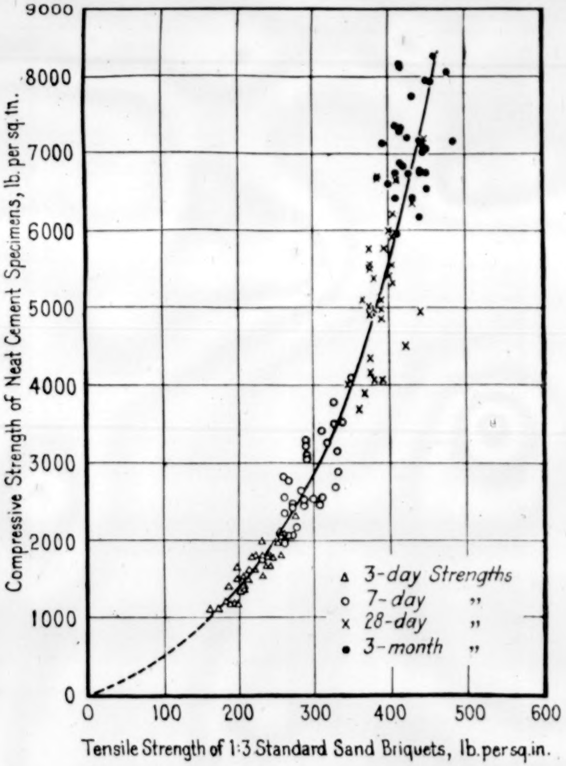

FIG. 4.—Relation of Compressive Strength of Neat Cement to Tensile Strength of 1:3 Standard Sand Mortar.

Tension tests of briquets of 1:3 standard sand mortar of A.S.T.M. normal consistency.

Compression tests of 2-in. cubes or 2 by 4-in. cylinders of neat cement mixed with 42 per cent of water by weight.

Plotted values based on average of tests by forty-six laboratories.

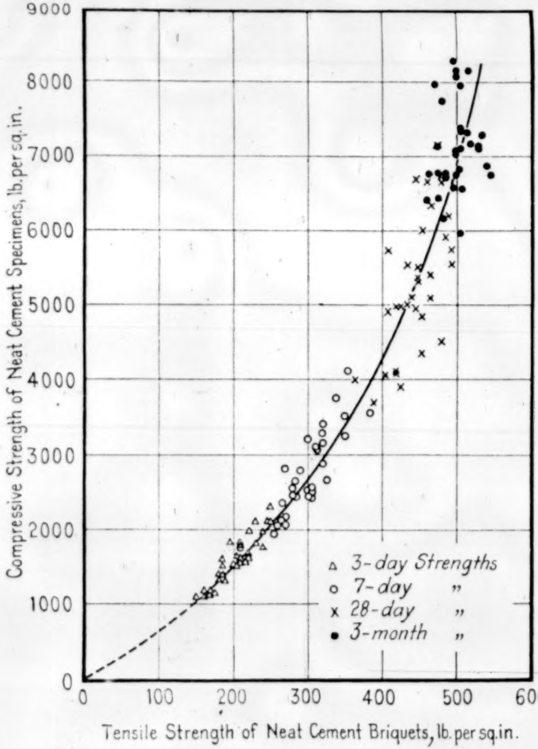

FIG. 5.—Relation of Compressive to Tensile Strength of Neat Cement.

Tension tests of briquets and compression tests of 2-in. cubes or 2 by 4-in. cylinders mixed with 42 per cent of water by weight.

Plotted values based on average of tests by forty-seven laboratories.

plus or minus values would be the best criterion of the concrete strength. The standard briquets and neat compression specimens rated about the same by this method.

In addition to the studies described above many other studies were made comparing the results of the cement tests with the concrete tests. All of these studies showed that none of the 3 types of specimen used possessed a marked advantage over the others as a criterion of concrete strength. Furthermore, no one of the 3 types of specimen had the characteristics desired in a test for use as a means of measuring the strength of a cement in concrete.

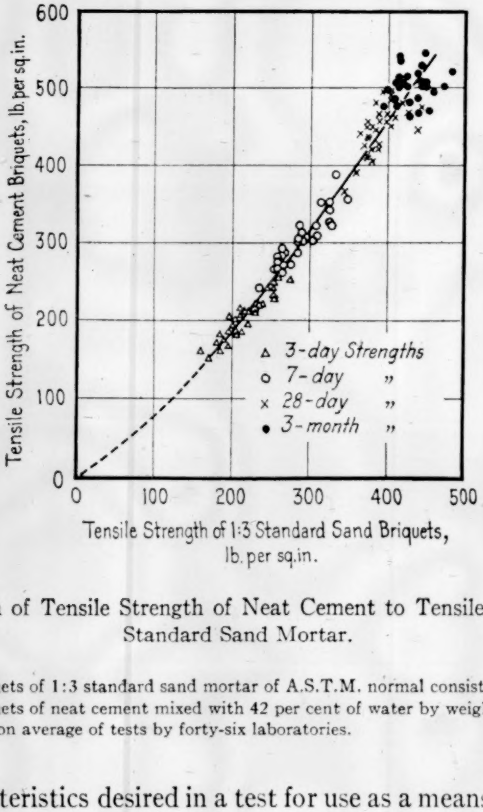

FIG. 6.—Relation of Tensile Strength of Neat Cement to Tensile Strength of 1:3 Standard Sand Mortar.

Tension tests of briquets of 1:3 standard sand mortar of A.S.T.M. normal consistency.
Tension tests of briquets of neat cement mixed with 42 per cent of water by weight.
Plotted values based on average of tests by forty-six laboratories.

Strength Relations for Neat Cement and 1:3 Mortar Specimens.—The relations between the tensile strengths of 1:3 standard sand mortar and neat cement and the compressive strength of neat cement are shown in Figs. 4 and 5. These two diagrams are similar in character but are not coincident over their entire range. In both diagrams the plotted points at the later ages show a greater spread from the average curve than at 3 and 7 days.

The relation between the tensile strengths of neat cement and 1:3 standard sand briquets is shown in Fig. 6. In general, the plotted points lie close to the curve, showing that there is a fairly well-defined relationship between the tensile strengths of the fluid neat cement and the 1:3 mortar mixtures.

Age-Strength Relations for Concrete, Neat Cement and 1:3 Mortar.—The grand average compressive strengths of the fluid neat cement specimens, tensile strengths of fluid neat cement and 1:3 mortar briquets and the grand average concrete strengths from the 32 cements (Tables III to VI) were as follows:

Specimen	Average Strength, lb. per sq. in.			
	3 days	7 days	28 days	3 months
Fluid neat 2-in. cubes or 2 by 4-in. cylinders (47 Laboratories)	1590	2720	5230	7100
Fluid neat cement briquets (47 Laboratories)	200	295	445	500
1:3 standard sand briquets (46 Laboratories)	215	290	390	430
Concrete 6 by 12-in. cylinders (2 Laboratories)	1100	....	....	....
Concrete 6 by 12-in. cylinders (6 Laboratories)	....	1850	3120	....

Age-strength relations for the concrete, neat cement and 1:3 mortar specimens from each of the 32 cements are shown in Fig. 10.

In further studies to determine which of 3 types of test specimens indicate most accurately the strength quality of the cement in concrete, the curves showing the relation between age and strength for each cement were compared with the average age-strength curve for all cements for a given type of specimen. For purpose of comparison the cements that closely followed the average curve were placed in one group. Two other groups were made for the cements whose age-strength curves were of the same general trend as the average curve but were either appreciably (about 10 per cent or more) higher or lower than the average curve. It was found that in some cases 5 additional groups were necessary to indicate the trend of the age-strength curve. These special groups were mainly for two reasons, one that some of the cements gave relatively high early strength but were about average at 3 months, the other that some gave low early strength but were up to the average at 3 months; three other groups were made which seemed to indicate best the general trend of a few cements.

The concrete age-strength curves were also grouped in the same manner and comparisons made as to the reliability of the different types of test specimen in indicating the behavior of the cement in concrete. In making these comparisons concrete strengths were available only to 28 days so that the departure from the average trend after that age was not considered.

In the neat compression tests 24 out of 32 cements, in the 1:3 standard sand tension tests 23 of the 32 cements, and in the neat cement tension tests 19 of the 32 cements fall in the groups indicated by the concrete tests. These results confirm those described above under comparison of neat cement, 1:3 mortar and concrete tests by 6 laboratories.

TABLE X.—TEMPERATURE DATA.

Temperatures are the average of the daily maximum and minimum temperatures reported by a given laboratory. Average room temperatures and relative humidity readings are only for those days on which specimens were made. In general, the curing water temperatures only cover the 28-day period after the last specimen was placed in the curing water; temperature data after that period were generally incomplete.

Laboratory	Date of Molding Specimens, 1927		Relative Humidity Air of Room			Temperature, deg. Fahr.								
						Air of Room			Mixing Water			Curing Water		
	Started	Finished	Average	High	Low	Average	High	Low	Average	High	Low	Average	High	Low
No. 1	Mar. 6	Mar. 14	75	81	70	73	76	70	70	72	68	70±5	..	..
No. 2	May 3	Aug. 16	72	87	55	79	84	74	71	73	70	71	73	70
No. 3	Feb. 14	Mar. 22	30	..	..	71	72	69	70	71	69	70	74	65
No. 4	Feb. 15	May 6	71	77	58	72	76	68	73	75	68	71	73	67
No. 6	Feb. 25	Mar. 11	43	49	38	75	78	73	74	75	73	74	74	74
No. 7	May 19	July 15	26	47	13	74	95	59	67	68	62	67	77	64
No. 9[a]	Feb. 23	Mar. 2	91	..	..	70	73	69	68	73	68	70	72	66
No. 9[b]	May 9	May 17	92	..	..	73	76	68	73	75	68	71	75	68
No 10	Mar. 4	Mar. 30	55	67	43	70	74	64	68	71	64	70	77	63
No. 11	Mar. 2	Apr. 9	71	74	67	73	77	71	71	74	70	65	68	60
No. 12	Feb. 8	Feb. 21	42	53	33	72	74	70	70	71	68	70	75	66
No. 13	July 25	Aug. 6	..	..	..	78	86	70	80	88	72	72	80	69
No. 14	Feb. 16	Mar. 16	88	92	85	70	72	68	69	70	67	69	71	67
No. 15	Feb. 9	Mar. 4	39	62	29	73	76	67	70	71	68	70	77	65
No. 16	Feb. 16	Apr. 1	41	57	34	70	74	64	70	70	70	70	75	61
No. 17	Feb. 10	Mar. 15	46	71	28	73	78	70	71	75	69	70	72	68
No. 18	Mar. 7	Mar. 31	..	..	..	72	76	70	69	70	67	69	73	66
No. 19	Feb. 16	Mar. 23	26	54	12	77	80	74	76	78	72	67	72	64
No. 20	Feb. 17	Apr. 2	37	51	28	71	79	68	69	76	65	70	73	67
No. 21	Mar. 1	Apr. 28	73	83	69	74	80	63	72	79	63	70	75	66
No. 22	Feb. 14	May 4	..	..	..	72	73	67	72	73	67	68	71	65
No. 23	Mar. 9	May 14	40	68	24	71	78	67	69	79	64	66	72	58
No. 24	Mar. 4	Mar. 25	38	50	25	70	74	68	70	71	69	69	71	66
No. 25	Feb. 24	Mar. 11	46	77	28	65	72	58	70	70	70	69	73	61
No. 26	Mar. 11	Mar. 22	57	62	55	70	71	69	70	72	65	70	73	67
No. 27	Feb. 9	Mar. 16	..	..	..	72	78	66	68	76	57	69	74	65
No. 28	Mar. 2	Apr. 4	49	63	38	72	77	70	70	70	70	71	72	66
No. 29	Mar. 4	Mar. 23	..	..	..	73	79	63	70	70	70	70	76	66
No. 30[a]	Mar. 28	Apr. 14	36	52	28	69	74	65	70	70	70	70	70	70
No. 30[b]	Mar. 28	Apr. 13	42	56	28	71	72	69	70	70	70	70	70	70
No. 31	..	..	..	..	..	..	..	..	..	..	..	..	..	..
No. 32	Feb. 21	Apr. 27	43	63	36	72	75	70	71	73	70	68	74	64
No. 33	Feb. 9	Mar. 24	64	70	58	72	76	69	70	72	66	68	70	66
No. 34	Mar. 10	Apr. 1	61	73	48	76	83	68	69	70	67	72	76	66
No. 35	Feb. 14	Apr. 19	58	72	47	72	77	65	70	70	70	67	72	58
No. 36	Feb. 18	Mar. 6	59	70	48	73	76	70	70	70	70	70	74	67
No. 37	Feb. 8	Mar. 25	..	..	..	73	76	70	70	70	70	70	72	70
No. 38	Mar. 7	Apr. 16	56	71	48	72	75	67	71	74	68	71	76	66
No. 39	Feb. 14	Feb. 26	66	82	47	75	75	73	70	70	70	72	73	71
No. 40	Feb. 15	Mar. 29	..	..	..	73	78	66	70	70	70	69	79	59
No. 41	Feb. 18	Apr. 13	47	58	39	71	74	70	70	70	70	70	73	68
No. 43	Feb. 14	Apr. 4	45	54	40	72	80	63	70	70	70	69	75	55
No. 44	May 2	June 4	..	..	..	73	78	67	71	74	67	70	74	68
No. 45	Feb. 15	May 4	28	45	18	78	86	74	..	..	..	71	76	68
No. 47	May 3	May 31	..	..	..	..	..	..	..	..	..	70	72	68
No. 48	Feb. 14	Mar. 21	47	60	36	74	83	66	75	84	70	68	77	48
No. 49	..	..	..	..	..	..	..	..	..	..	..	..	..	..
No. 51	Feb. 22	Apr. 22	37	42	31	70	77	64	..	..	..	70	74	65
No. 52	Feb. 19	May 8	..	..	..	65	70	62	64	70	61	62	64	56

[a] Fluid cement pastes. [b] 1:3 standard sand briquets.

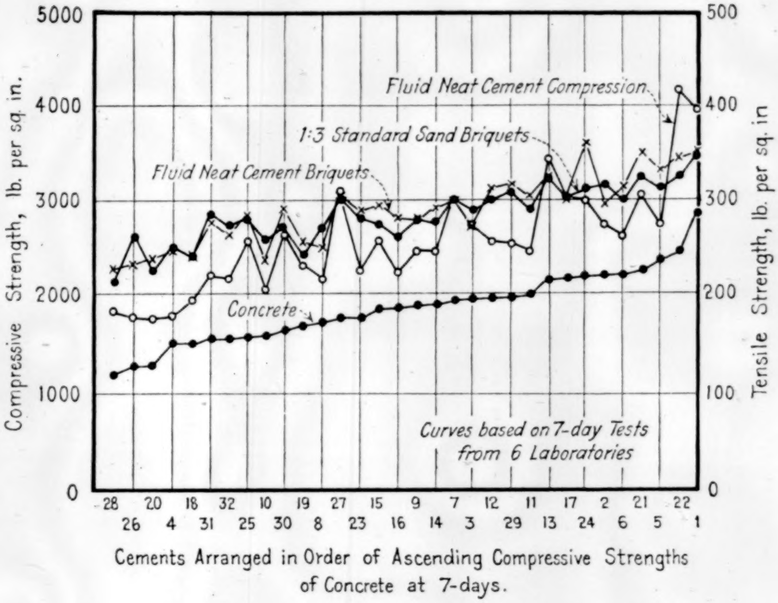

FIG. 7.—Comparison of Cement and Concrete Tests at 7 Days.

Compression tests of 6 by 12-in. concrete cylinders. Concrete mix, 1:2.4:3.6 by weight. Nominal water-cement ratio, 0.90.

Tension tests of briquets and compression tests of 2-in. cubes or 2 by 4-in. cylinders of neat cement mixed with 42 per cent of water by weight.

Tension tests of briquets of 1:3 standard sand mortar of A.S.T.M. normal consistency.

Plotted values based on average of tests by six laboratories.

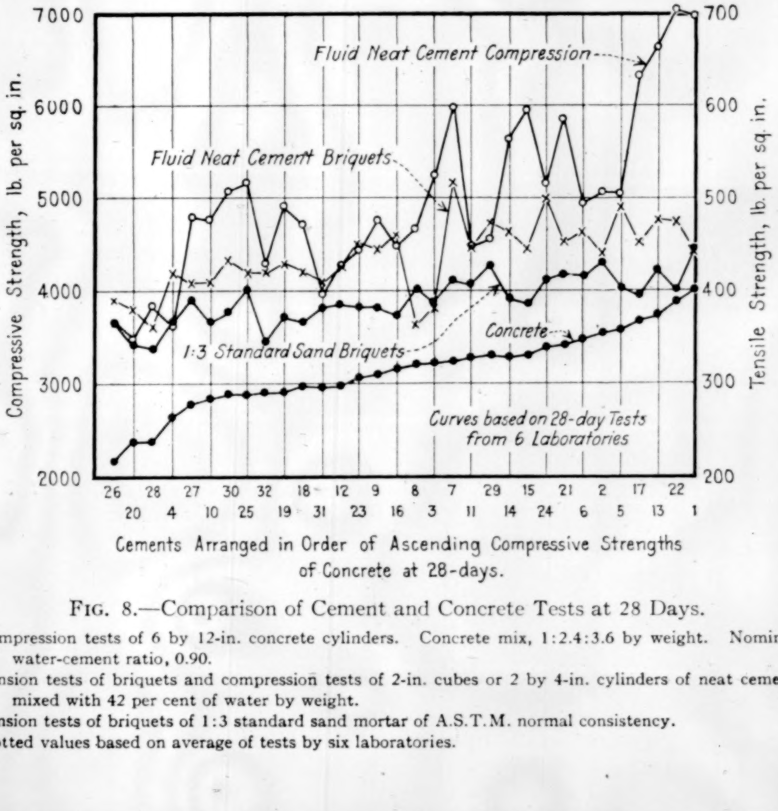

FIG. 8.—Comparison of Cement and Concrete Tests at 28 Days.

Compression tests of 6 by 12-in. concrete cylinders. Concrete mix, 1:2.4:3.6 by weight. Nominal water-cement ratio, 0.90.

Tension tests of briquets and compression tests of 2-in. cubes or 2 by 4-in. cylinders of neat cement mixed with 42 per cent of water by weight.

Tension tests of briquets of 1:3 standard sand mortar of A.S.T.M. normal consistency.

Plotted values based on average of tests by six laboratories.

TABLE XI.—SUMMARY OF REJECTIONS BY INDIVIDUAL LABORATORIES ON THE BASIS OF THE PRESENT A.S.T.M. STANDARD SPECIFICATIONS AND TESTS FOR PORTLAND CEMENT (SERIAL DESIGNATION: C 9 - 26)

Laboratory	Cements Not Passing A.S.T.M. Requirements for Tensile Strength at 7 days (A) and 28 days (B)																																Number of Rejections		Cement Rejected				
																																			Fineness	Time of Setting		Soundness	Chemical Analysis[a]
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	7 days	28 days		Initial	Final		
COMMERCIAL TESTING LABORATORIES																																							
No. 1	..	..	..	..	..	..	..	..	..	B	..	..	..	..	..	..	..	..	..	AB	..	..	..	..	..	..	B	AB	..	B	..	..	2	5	..	..	..	..	..
No. 3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	A	..	..	..	..	1	..	..	..	..	..	..
No. 4	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	A	..	..	..	..	1	..	..	..	..	..	..
No. 5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
No. 6	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	B	..	..	..	..	..	1	..	25	..	5	..
No. 7	..	..	AB	AB	..	B	AB	A	AB	AB	AB	B	..	..	B	..	..	AB	AB	..	..	..	AB	..	AB	AB	B	AB	B	AB	B	..	14	19	30	..	..	..	..
Total 7 days	..	..	1	1	..	..	1	1	1	1	1	..	..	..	..	..	..	1	1	1	..	..	1	..	1	1	..	4	..	1	..	..	18	..	1	1	..	1	..
Rejected 28 days	..	..	1	1	..	1	1	..	1	2	1	1	..	..	1	..	..	1	1	1	..	..	1	..	1	1	2	3	1	2	1	..	..	25					
GOVERNMENT, STATE AND MUNICIPAL LABORATORIES																																							
No. 9	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
No. 10	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	25	..	..	4
No. 11	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
No. 12	..	..	..	A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	A	..	..	..	..	..	..	..	..	..	..	..	..	2	..	..	..	2, 8, 9, 10 11, 23, 15	..	..
No. 13	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	25	..	..	..
No. 14	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	A	2	..	..	..	..	..	..
No. 15	..	..	..	A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	A	..	..	..	..	..	..	..	A	..	..	..	..	3	..	..	31	..	..	..
No. 16	..	..	B	A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	A	..	..	..	..	2	1	..	12	..	..	4, 25
No. 17	..	..	AB	AB	B	B	B	B	AB	AB	B	B	AB	AB	AB	AB	AB	AB	AB	AB	B	B	B	B	AB	AB	A	AB	..	AB	AB	AB	19	28	..	..	..	..	..
No. 18	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	A	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..
No. 19	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4, 30	..	..	..	4, 25
No. 20	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	B	A	..	..	..	..	..	..	..	AB	..	..	..	..	2	2	..	..	..	..	..
No. 21	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	B	AB	A	A	..	..	A	..	..	..	B	AB	..	AB	A	AB	7	6	4	25, 31	..	..	..
No. 22	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	A	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..
No. 23	..	..	A	B	..	..	..	..	..	A	..	B	..	..	B	B	B	B	B	..	B	..	B	..	A	..	B	AB	B	AB	A	B	6	14	..	12, 25	..	..	..
No. 24	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
No. 25	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
No. 26	..	..	..	..	..	..	..	..	..	..	B	..	..	..	..	..	..	..	..	A	..	..	..	..	..	B	..	A	..	..	..	..	2	2	..	..	..	..	..
No. 27	..	..	..	..	..	..	..	..	..	A	..	..	..	..	..	..	..	..	AB	AB	..	..	..	..	..	..	..	AB	..	..	..	..	4	3	4	..	..	..	..
Total 7 days	..	..	2	4	..	..	..	..	1	3	..	..	1	1	1	2	1	2	3	9	..	..	1	..	2	1	1	8	..	3	3	3	51	..	4	8	7	..	5
Rejected 28 days	..	..	2	2	1	1	1	1	1	1	2	2	1	1	2	2	3	3	4	2	2	1	2	1	1	2	2	5	1	3	1	3	..	56	..	..	..	..	..
PORTLAND CEMENT MANUFACTURERS LABORATORIES																																							
No. 28	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	30	12, 25, 31	..	..	..
No. 29	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	12, 31, 32	..	..	..
No. 30	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	A	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..
No. 31	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4, 18, 30	25	..	..	..

PORTLAND CEMENT MANUFACTURERS LABORATORIES—*Continued*

No. 32																																	..	..	..	..	..	..	..
No. 33																		A		A						A		AB			AB	B	5	3	..	12	..	..	..
No. 34																			A	A								AB					4	1	..	25, 32	..	..	..
No. 35																																	..	..	..	..	..	..	4, 25
No. 36																																	..	..	..	..	..	..	..
No. 37																																	..	..	..	..	..	..	4
No. 38																												B					..	1	..	12, 31	..	..	..
No. 39																																	..	..	..	..	2	..	..
No. 40																																	..	..	..	12, 25 31, 32	..	..	..
Total Rejected 7 days																		2	1	2						1		2			1		10	..	4	16	1	..	3
28 days																												3			1	1	..	5	..	..	..	..	..

RAILROAD LABORATORIES

No. 41																														B			..	1	..	12, 25 31, 32	..	..	..
Total Rejected 7 days																																	..	..	..	4	..	..	..
28 days																														1			..	1	..	..	..	..	..

UNIVERSITY AND COLLEGE LABORATORIES

No. 43																				A								AB					2	1	..	25	..	..	..
No. 44				A						A								A	A	AB						AB		B				B	6	4	..	..	2, 4, 6, 8, 10 14, 18, 20 21, 22, 26	..	
No. 45																				A								AB		A	AB		4	2	..	25, 31	..	..	..
No. 47				A																A								AB					3	1	..	..	..	..	..
No. 48			A																													A	2	..	4, 15, 25, 30	31	..	..	..
No. 49				A																													1	..	..	..	..	..	..
No. 51	B		AB	B	B	B	B	B	B	B	B	B			B	B	B	B	AB	AB	B		B	B		B		B		AB	B	AB	5	25	4, 30	..	21, 22, 23	..	..
No. 52				A																A								A					3	..	..	12, 31	..	3, 13, 16, 17 20, 21, 22 27, 28, 32	..
Total Rejected 7 days			2	4						1								1	2	6						1		4		2	1	2	26	..	..	..	..	..	..
28 days	1		1	1	1	1	1	1	1	1	1	1			1	1	1	1	1	2	1		1	1		2		5		1	2	2	..	33	6	6	14	10	..
Grand Total Rejected 7 days			5	9			1	1	2	5	1		1	1	1	2	1	6	7	18			2		3	4	1	18		6	5	5	105	..	15	35	22	10	8
28 days	1		4	4	2	3	3	2	3	4	4	4	1	1	4	3	4	5	6	5	3	1	4	2	2	5	4	16	2	7	5	6	..	120	..	..	..	..	..

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[a] Five laboratories reported analyses of cements; all of them reported cement 4 high in MgO; 3 laboratories reported cement 25 high in SO_3.

SUMMARY OF REJECTIONS IN MISCELLANEOUS TESTS

(Number of laboratories rejecting given in parentheses)

Fineness: Cements No. 4(6), 15(1), 18(1), 25(1), 30(6).
Initial time of setting: Cements No. 12(9), 25(12), 31(10), 32(4).
Final time of setting: Cements No. 2(3), 4(1), 6(1), 8(2), 9(1), 10(2), 11(1), 14(1), 15(1), 18(1), 20(1), 21(2), 22(2), 23(2), 26(1).
Soundness: Cements No. 3(1), 5(1), 13(1), 16(1), 17(1), 20(1), 21(1), 22(1), 27(1), 28(1), 32(1).
Chemical Analysis: Cements No. 4(5), 25(3).

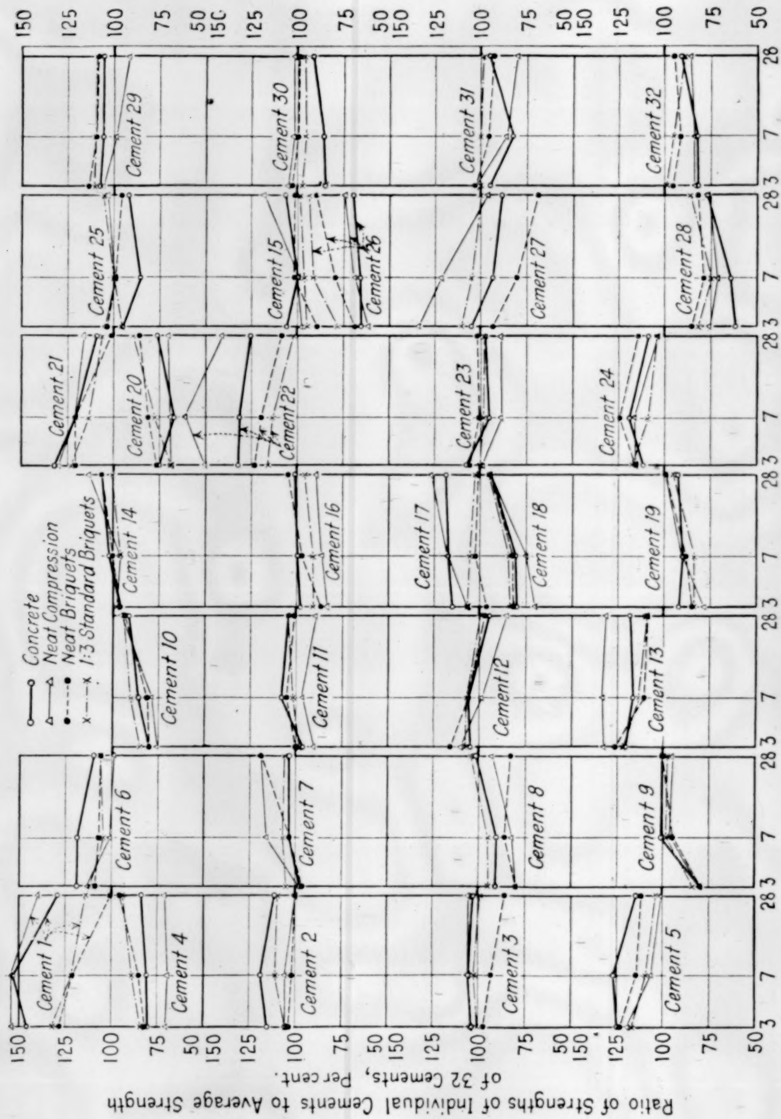

FIG. 9.—Age-Strength-Ratio Relations for 32 Cements Based on Average Strengths for Six Laboratories.

Three day concrete strength ratios based on average of two laboratories only.

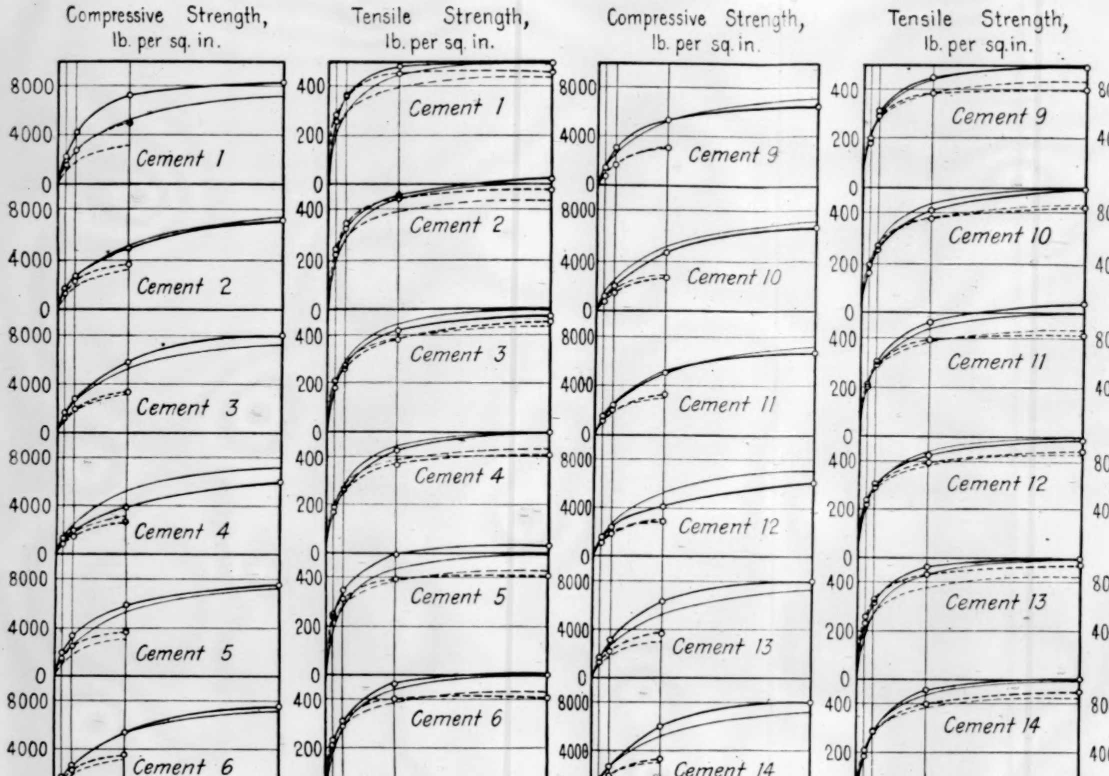

Fig. 10.—Age-Strength

PLATE VI.
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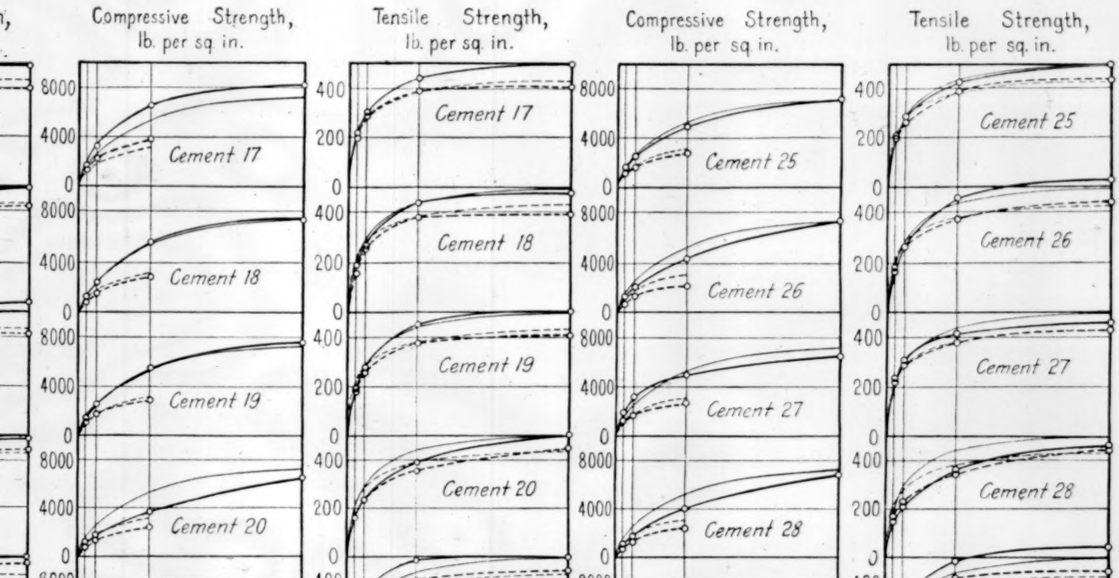

Note: Plotted Strengths of Neat Cement and 1:3 Mortar Specimens for a given Cement are the Average Strengths for 46 or 47 Laboratories. Plotted Concrete Strengths at 3 days are the Average Strengths for 2 Laboratories, and at 7 and 28 days, the Average Strengths for 6 Laboratories.

Data from Tables III, IV, V and VI.

rength Relations for Cements.

A number of interesting points were shown by the age-strength curves. In the concrete compression tests all but one of the cements had age-strength curves of the same general shape as the average curve. In the neat compression tests a greater number of groups were required to classify the various cements, but there was a very close agreement in the strengths of many of the cements at the 3-month period, indicating that differences in the neat compressive strengths are less pronounced at the age of 3 months than at the early ages. In the 1:3 briquet tests only 3 cements were appreciably lower than the average curve at the earlier ages.

The tension tests of neat cement and 1:3 mortar briquets show much less difference between the various cements than do the neat cement or concrete compression tests. In general, there is materially less difference between the various cements at 3 months for any method of test than at the early ages, which would tend to question the reliability of early strength tests as a criterion of ultimate strength quality of a cement.

Comparisons of Results of Cement Tests with the Requirements of the A.S.T.M. Specifications.—Table XI summarizes comparisons of the results of the tests on the various cements by individual laboratories with the requirements of the A.S.T.M. Standard Specifications and Tests for Portland Cement (C 9 - 26). Comparisons are based on results of the strength tests of 1:3 standard sand briquets and miscellaneous tests of the cements by 46 laboratories and chemical analyses by 5 laboratories.

This table shows that if the results of 4 laboratories are omitted, all but one or two of the 32 cements used in this investigation passed the requirements of the A.S.T.M. Specifications in the tests of nearly all of the remaining 42 laboratories. In the tests of 4 laboratories, 14, 19, 6, and 5 of the 32 cements respectively failed to meet the requirements for 7-day tensile strength and 19, 28, 14 and 25 of the 32 cements failed to meet the requirements for 28-day tensile strength. Approximately 60 per cent of the strength rejections were made by these 4 laboratories alone, indicating that their apparatus or methods were faulty and that the strengths they obtained did not truly reflect the strength quality of the cement. The reasons for the low strengths obtained by these 4 laboratories are not apparent.

In this connection the information given in Table X on the temperature and humidity conditions during the making and curing of the specimens is of interest. It will be noted that there was a considerable range in both temperature and humidity. The range in the average values was as follows:

	MAXIMUM	MINIMUM	RANGE
Relative Humidity, per cent	91	26	65
Temperature of Molding Room, deg. Fahr	79	65	14
Temperature of Mixing Water, deg. Fahr	80	64	16
Temperature of Curing Water, deg. Fahr	74	62	12

Probably the most important cause of the wide variations in the results obtained by the different laboratories in these tests was the lack of control of the many factors which are known to affect the results of cement tests. It cannot be too strongly emphasized that careful attention must be given to the details of making, curing and testing the specimens as described in the Standard Specifications and Manual of Cement Testing, if uniformity in results is to be obtained.

SUMMARY AND CONCLUSIONS

This investigation was made: (1) to compare the uniformity of compression tests of 2-in. neat cement cubes (or 2 by 4-in. cylinders) and tension tests of neat briquets mixed with 42 per cent of water by weight of cement with the uniformity of tension tests of 1:3 standard sand briquets; (2) to compare neat cement strengths (tension and compression) and 1:3 standard sand mortar strengths; (3) to obtain data to determine the value of the three tests of cement (neat cement compression specimens, neat cement tension specimens, and standard sand mortar briquets) as a measure or indication of the strength of a cement in concrete; (4) to obtain data on which to base a possible specification requirement for cement strength when tested in fluid cement-water mixtures at 3, 7 and 28 days or in standard sand briquets at 3 days.

Forty-seven laboratories cooperated in carrying out strength and miscellaneous tests outlined by this sub-committee on 32 portland cements purchased from dealers. Strength tests included tension tests of 1:3 standard sand briquets of A.S.T.M. normal consistency, tension tests of neat cement briquets and compression tests of neat cement 2-in. cubes (or 2 by 4-in. cylinders) mixed with 42 per cent of water by weight of cement, at ages of 3, 7 and 28 days and 3 months. These strength specimens were made 3 in a set from a single batch for test at a given age. In addition to the cement tests, 6 laboratories made tests on 6 by 12-in. concrete cylinders from the 32 cements at ages of 7 and 28 days. The concrete was mixed by hand following A.S.T.M. standard methods in batches of sufficient size for one cylinder. The same weights of cement, mixing water and fine and coarse aggregate were used for a batch by all laboratories but each laboratory used local aggregates.

The results of the miscellaneous tests on the cement, which included normal consistency, time of setting with the Vicat needle, soundness, fineness and chemical analyses, are not given in this report but are discussed in the reports of Sub-Committees I, III, V and VI.

The complete program included a total of about 62,000 strength and miscellaneous tests.

This series of tests involved not only a comparison of methods of test, but of necessity also a comparison of the work of the laboratories making the tests and of the 32 cements used. The tests have brought out certain facts which indicate the direction which further studies should take. These may be summarized as follows:

1. The most outstanding feature of this series of tests is the wide variation between the results from different laboratories. This was nearly as pronounced in the case of the A.S.T.M. standard methods as in the other methods tried and shows the great necessity for careful adherence in every detail to the methods outlined in Standard Specifications C 9 and in the Manual of Cement Testing for mixing, molding, curing and testing.

2. Conclusions 3 to 7 show a comparison of the 3 types of test which were tension tests of standard mortar briquets, tension tests of fluid neat cement briquets (mixed with 42 per cent of water by weight), and compression tests of fluid neat cement (2-in. cubes or 2 by 4-in. cylinders). Nothing is brought out in these comparisons to warrant changing at the present time to another method for strength tests.

3. Judged by the mean variations in the tests by individual laboratories, there was no marked difference in the uniformity of the strengths of the 3 specimens from a batch in the 3 types of cement test.

4. The average mean variation in the 7 and 28-day strengths of the three 6 by 12-in. concrete cylinders in a set (made on 3 different days) was 5.4 per cent as compared with 3.9 per cent for the three types of cement tests (specimens made 3 in a batch).

5. Comparisons of the uniformity of strengths, as between laboratories, showed that the mean variations in the tests of standard mortar briquets were but slightly lower than the mean variations in the neat cement briquet tests but ranged from about 60 to 75 per cent of the values obtained in the compression tests of neat cement.

6. Comparisons of the strengths from the 3 types of cement test with the corresponding concrete strength showed that none of them possessed a marked advantage over the others as a criterion of concrete strength. Furthermore, no one of the 3 types of test had the characteristics desired in a test for use as a means of measuring the strength property of a cement in concrete.

7. Curves plotted to show the inter-relationships of the strengths of the three types of test indicated a well-defined relation between the tensile strengths of the neat cement and the standard mortar briquets at all ages. However, the relations between these tensile strengths and the compressive strength of the neat cement were not so well defined, the plotted points falling fairly close to the average curve at the early ages but showing marked deviations at the latter ages.

8. Two features stand out in the results of the compression tests of concrete by the six laboratories: (*a*) a range in the grand average strengths of the concretes made with the 32 cements from 1610 lb. per sq. in. for the laboratory reporting the lowest strength to 2190 lb. per sq. in. for the one reporting the highest results at an age of 7 days, and from 2510 to 3870 lb. per sq. in. at 28 days for the same laboratories, the results of the four other laboratories being distributed between these extremes; and (*b*) a substantial concordance between the results obtained by the individual laboratory for a given cement and the corresponding value obtained by multiplying the average of the six laboratories for each cement by a "laboratory factor" found by dividing the grand average of the six laboratories for all the cements by the grand average for the individual laboratory. The grand average strengths at 28 days for the individual laboratories were 80, 90, 94, 103, 109, and 124 per cent of the grand average for the six laboratories. The differences in results may be attributed largely to differences in manipulation in mixing and fabricating the specimens and to differences in the aggregates used, but doubtless other conditions also affected the results.

Respectfully submitted on behalf of the sub-committee,

P. H. BATES,
Chairman.

DISCUSSION

MR. HERBERT J. GILKEY[1] (*presented in written form*).—Although disappointing for the immediate purposes intended, in their inconclusiveness, the results from the recent investigations sponsored by Committee C-1 should, and no doubt will, prove to be a vast reservoir of information for future interpretation and use. **Mr. Gilkey.**

It is indeed a rare thing to have assembled for study and comparison so many representative cements. It is still more rare to be able to compare one's own results with those of other laboratories and operators and later to have available for study authentic chemical analyses and other information that it would not have been feasible to obtain first hand. The regulation job for any participating laboratory was such a big one, that it was naturally impossible to undertake very much in addition to the prescribed routine. The writer's laboratory did, however, amplify the program in certain minor respects and he feels that those findings should be recorded for whatever of future significance they might develop.

The main digressions made were as follows:

(*a*) Some data were collected upon certain minor and secondary characteristics of the cements and specimens such as specific gravity, color and the weight changes that take place during curing.

(*b*) All tension test briquet halves were fitted together and replaced in the curing tanks after testing, a rubber band being used to keep the halves in contact. At various intervals they were removed from the water and retested, after which they were again refitted and stored. Thus successive measures of tensile autogenous healing were obtained for every briquet made from all the cements.

SPECIFIC GRAVITY

Although the specific gravity is no longer considered to have any important connection with the desirable properties of a cement, the writer had specific gravity determinations made on all the different samples. These were checked by several trials each by two different operators. The results are given below:

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[1] Associate Professor of Civil Engineering, University of Colorado, Boulder, Colo.

Mr. Gilkey.

	CEMENT No. 1	CEMENT No. 2	CEMENT No. 3	CEMENT No. 4	CEMENT No. 5	CEMENT No. 6	CEMENT No. 7
Specific Gravity....	3.12	3.14	3.13	3.10	3.10	3.13	3.11

	CEMENT No. 8	CEMENT No. 9	CEMENT No. 10	CEMENT No. 11	CEMENT No. 12	CEMENT No. 13	CEMENT No. 14
Specific Gravity....	3.14	3.11	3.14	3.10	3.18	3.14	3.14

	CEMENT No. 15	CEMENT No. 16	CEMENT No. 17	CEMENT No. 18	CEMENT No. 19	CEMENT No. 20	CEMENT No. 21
Specific Gravity....	3.08	3.08	3.15	3.12	3.10	3.06	3.10

	CEMENT No. 22	CEMENT No. 23	CEMENT No. 24	CEMENT No. 25	CEMENT No. 26	CEMENT No. 27	CEMENT No. 28
Specific Gravity....	3.16	3.15	3.12	3.15	3.16	3.13	3.20

	CEMENT No. 29	CEMENT No. 30	CEMENT No. 31	CEMENT No. 32	MAXIMUM	MINIMUM	AVERAGE
Specific Gravity....	3.14	3.13	3.20	3.19	3.20	3.06	3.13

COLOR[1]

Although the color is not usually considered to be of any great importance in its influence upon the properties, the lighter colors may be some indication of finer grinding.

Among the thirty-two samples there was a wide and interesting color range which appeared as clearly in the colors of the neat cement and 1:3 standard sand specimens as it did in the cement itself. Many of the colors were very similar, but the approximate order from light to dark was: cements Nos. 9, 15, 20, 26, all light gray; Nos. 30, 11, 10, 27, 3, 21, 13, 7, 22, 25, classified as tans; Nos. 24, 17, 23, 19, 28, 14, 18, 1, 4, 16, medium tan or gray; Nos. 31, 32, 5, 8, 29, 2, 6, 12, all dark green. Cement No. 9 was the lightest and cement No. 12 the darkest of the lot, according to the writer's classification.

The specimens from cement No. 23 were all of a vivid green inside, while those from cements Nos. 14 and 25 had a distinct brown or reddish cast.

WEIGHTS

All specimens were weighed as removed from the molds for moist storage and again as tested. Only the summarized results are given here, as shown in the accompanying Table I.

Upon immersion there is probably an initial and fairly constant volume of water absorbed more or less proportional to the volume of voids or capillary passages in the mortar or concrete. This is mechanical.

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[1] A good digest of this subject is given in *Concrete* (Cement Mill Edition), April, 1928, pp. 111–112.

Mr. Gilkey.

There then doubtless follows a gradual and increasing acquisition of water as curing proceeds, this water going into chemical combination with the cement and being more or less permanently held after the specimen is removed from moist storage. (Of course some of the capillary moisture is also held against ready evaporation by capillary attraction.) The amount of moisture that is chemically utilized will naturally be proportional to the amount of cement that is present in a specimen. The range shown in Table I would also indicate that cements differ in their water requirements during a given curing period. The relative amounts of water utilized by different cements at different stages of curing must be intimately related to the chemistry of hardening and would therefore appear to be one of the important items meriting the attention of qualified observers. In this territory the writer does not classify himself as such.

TABLE I.—INCREASE IN WEIGHT OVER WEIGHT AS STORED.

(Expressed as percentage of weight as stored)

Cement	Neat Cement 2 by 4-in. Cylinders (Weight, 380 to 401 g.)				Neat Cement Briquets (Weight, 113 to 126 g.)				1:3 Standard Sand Briquets (Weight, 128 to 140 g.)			
	3 days	7 days	28 days	3 months	3 days	7 days	28 days	3 months	3 days	7 days	28 days	3 months
No. 1	1.68	2.09	3.48	4.18	1.69	2.53	3.89	4.42	0.63	1.63	2.74	2.07
No. 2	1.64	2.00	2.46	3.04	2.04	3.19	2.03	3.79	1.44	1.19	1.32	1.70
No. 3	1.51	2.13	2.89	3.60	1.22	2.86	4.06	4.58	2.50	2.43	2.78	3.53
No. 4	1.96	1.41	2.35	3.66	1.37	1.98	2.69	3.62	1.35	1.91	2.16	2.99
No. 5	1.24	1.78	2.82	2.74	1.78	2.53	2.72	3.40	1.28	1.73	1.93	3.26
No. 6	1.44	1.77	2.84	3.96	2.41	2.46	3.63	4.47	1.39	1.15	1.80	2.85
No. 7	1.33	2.01	3.58	4.20	2.20	3.12	4.36	5.30	1.73	2.14	2.20	3.20
No. 8	1.50	2.18	2.34	2.78	1.87	2.60	2.92	4.79	1.46	1.57	2.06	3.31
No. 9	1.28	2.09	3.42	4.24	1.97	2.69	4.21	4.71	1.58	2.08	2.93	4.18
No. 10	1.30	1.82	2.96	2.94	2.13	2.52	....	3.87	1.02	1.83	....	3.66
No. 11	1.77	1.98	2.58	3.55	2.23	2.49	....	4.49	2.06	2.31	....	3.70
No. 12	1.61	1.91	2.34	3.46	2.33	2.08	....	3.83	1.35	1.48	....	2.87
No. 13	1.67	2.68	3.85	4.81	2.29	3.09	....	5.84	1.65	1.82	....	3.84
No. 14	1.19	1.83	2.72	3.36	2.62	3.14	....	5.33	2.41	1.83	....	3.45
No. 15	0.81	1.61	2.74	3.72	1.54	1.60	3.07	4.07	1.41	1.83	2.23	3.49
No. 16	1.17	1.87	2.81	4.02	1.86	2.80	2.97	4.37	1.13	1.31	2.05	3.29
No. 17	1.16	1.91	3.04	3.79	1.91	1.92	3.51	4.59	1.38	1.74	2.66	3.16
No. 18	1.54	1.24	2.46	3.60	1.38	1.84	3.10	4.36	1.23	1.48	2.37	2.77
No. 19	0.69	1.33	2.35	3.22	1.36	1.90	3.51	3.83	0.95	0.95	2.13	2.79
No. 20	0.98	1.54	1.90	3.00	1.93	2.33	2.40	2.97	0.61	1.07	1.53	2.24
No. 21	1.68	2.52	3.47	4.28	2.13	2.89	3.95	4.50	1.57	1.98	2.60	3.25
No. 22	1.76	2.46	3.34	4.32	2.16	3.18	4.68	5.33	0.92	1.51	2.81	3.48
No. 23	1.37	1.71	2.31	3.18	1.40	1.88	2.61	2.59	1.32	1.71	2.67	3.39
No. 24	1.15	1.90	2.92	3.57	1.88	2.97	4.39	4.41	0.89	1.29	2.57	3.40
No. 25	1.83	2.38	3.30	3.58	2.32	2.56	3.61	4.25	1.72	2.49	2.58	2.92
No. 26	0.81	1.39	2.13	2.78	1.39	1.81	3.02	3.45	0.82	0.80	1.74	2.27
No. 27	0.95	2.02	3.09	3.69	1.70	2.92	3.74	4.67	1.32	1.59	3.24	3.76
No. 28	0.73	1.44	1.77	2.92	1.89	2.35	3.57	4.50	1.46	1.71	2.71	3.52
No. 29	1.37	1.70	2.59	2.82	2.46	2.77	3.46	4.09	1.90	1.87	2.00	2.61
No. 30	0.76	1.29	2.97	3.58	2.59	3.07	4.79	4.72	1.97	2.17	3.55	4.57
No. 31	1.37	1.20	2.02	3.00	2.62	2.54	3.28	3.41	1.64	1.66	1.84	2.35
No. 32	1.47	1.63	2.35	2.36	2.27	1.99	3.21	3.68	1.59	1.46	2.52	2.83
Average	1.34	1.84	2.75	3.50	1.97	2.52	3.56	4.26	1.43	1.68	2.39	3.14
High.....	1.96	2.68	3.85	4.81	2.62	3.19	4.79	5.84	2.50	2.49	3.55	4.57
Low.....	0.69	1.20	1.77	2.36	1.22	1.60	2.03	2.59	0.63	0.80	1.32	1.70

NOTE.—The weight of neat cement briquets ranged from 113 to 126 g., while 1:3 standard sand briquets weighed from 128 to 140 g. as stored. Thus, the percentage for 1:3 standard sand briquets should be increased by about one-eighth to compare on volume basis.

Mr. Gilkey. The data of Table I indicate that the neat cement briquets had higher absorption in almost every instance than did the 2 by 4-in. neat cement cylinders made from the same batch and stored with the briquets. This would seem to indicate that the surface-volume ratio (considerably greater for the briquets) is also a pertinent factor.

The 1:3 standard sand briquets weighed from 10 to 15 per cent more than the neat cement briquets of the same size. On the basis of percentages absorption by weight, the differential between the standard sand and neat briquets is not therefore as great as the figures indicate. Nevertheless the neat briquets did absorb more water than those of the 1:3 mixture.

TENSILE AUTOGENOUS HEALING

By far the greatest amount of extra attention was devoted to the very striking phenomenon of tensile autogenous healing. The writer's first reconnaissance tests on tensile healing[1] gave negative results, but since that time he has found that tested tensile briquets of all proportions, relative water content, ages at initial test, etc., give measurable and sometimes startlingly high tensile strengths if the broken ends be carefully fitted together and the briquet is replaced in moist storage. Broken tension test briquets have been left with the halves detached and exposed to dry air for several months, then fitted together and reimmersed, with resulting healing. This healing seems to occur alike in stagnant and in circulating water. From the standpoint of gaining a better understanding of what happens when cement sets it would seem that this phenomenon may be of great importance.

As mentioned earlier, in the present investigation all of the tension test briquet halves, including both the neat cement briquets and the standard sand mortar briquets, were fitted together and replaced in the curing tanks after testing. From two to four retests were made on each briquet. Healing occurred only when the pieces were closely fitted together and held in position. Although no effort has been made to explain or analyze the findings, certain interesting points stand out:

1. Among both the neat cement and the 1:3 standard sand briquets, the maximum retest strengths attained were upon the first retest at 3.5 months of specimens initially fractured at 3 days. These show tensile retest strengths as high as 221 lb. per sq. in. for the neat cement and 143 lb. per sq. in. for the 1:3 standard sand briquets.

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[1] H. J. Gilkey, "The Autogenous Healing of Concretes and Mortars," *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part II, p. 470 (1926).

Mr. Gilkey.

2. In many individual cases the specimens initially tested at 7 days and retested at 3.5 months gave the maximum retest strength.

3. Specimens initially tested at 3 months and retested but two weeks later gave measurable recoveries, the highest being 33 lb. per sq. in. for neat cement and 4 lb. per sq. in. for 1:3 standard sand.

4. At the fifth breaking, fourth retest, the highest standard sand specimen gives 12 lb. per sq. in., slightly exceeding the highest neat cement at 11 lb. per sq. in.

5. All cements seem to show healing. Some show up better in relation to recovery from the earlier tests and *vice versa*. Ratings for a cement in the tests of neat cement briquets and in tests of 1:3 standard sand briquets are not always in agreement.

6. Healing only occurs in the presence of moisture.

The detailed data have been made available to Committee C-1 on Cement and in addition may serve as the basis of a further elaboration in the form of a technical paper by the author at some future time.

ACKNOWLEDGMENTS

Mr. C. L. Eckel, Head of the Department of Civil Engineering, encouraged the work. Wm. L. Eager, Cleland Feast, Smith Ketchum and Sartwell Egerton, students in Civil Engineering, assisted in making the tests and in the reduction of data.

REPORT OF COMMITTEE C-3

ON

BRICK

Committee C-3 has held three general meetings during the past year.

The committee recommends for publication as tentative, two proposed tentative specifications appended hereto:[1]

1. Proposed Tentative Specifications for Sand-Lime Building Brick.

2. Proposed Tentative Specifications for Concrete Building Brick.

The proposed Tentative Specifications for Concrete Building Brick are in effect a revision of the present Tentative Specifications for Concrete Brick (C 55 – 24 T),[2] the withdrawal of which is recommended.

The committee recommends revision of tentative specifications as given below:

Tentative Specifications for Building Brick (Made from Clay or Shale) (C 62 – 27 T).[3]—

Section 1.—Change from its present form: namely,

> These specifications cover building brick made from clay or shale and properly burned, suitable for use in the construction of buildings.

to read as follows:

> These specifications cover brick made from clay or shale and properly burned, intended for use in brick masonry.

Section 2. (a).—Change the note to the table of physical requirements from its present form: namely,

> NOTE.—Bricks of Grades *A* and *B* are usually hard or well-burned. Bricks of Grade *C* are usually underburned.

to read as follows:

> NOTE.—The above classifications are based on strength and do not necessarily measure weather resistance.

Section 3.—Omit the word "fairly" in the first sentence of this section.

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[1] See pp. 840 and 838, respectively.—ED.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 24, Part I, p. 813 (1924); also 1927 Book of A.S.T.M. Tentative Standards, p. 243.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 803 (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 241.

Tentative Specifications for Paving Brick (C 7 - 27 T).[1]—

Section 3.—Change Paragraph (*a*) to read as follows by the addition of the italicized words:

> Paving brick shall be manufactured from fire clay or shale, or a combination thereof, ***molded into the requisite shape and properly vitrified.***

Omit Paragraph (*b*), reading as follows:

> The material shall possess such physical and chemical properties that when molded into brick and properly vitrified, the resulting product will meet the requirements of these specifications.

Section 4. (*a*).—Change to read as follows by the omission of the words in brackets:

> [In addition to other tests mutually agreed upon,] the quality and acceptability of paving brick shall be determined by the Rattler Test[, as described in the Tentative Methods of Testing Brick (Serial Designation: C 67 - 27 T) of the American Society for Testing Materials, for the purpose of determining whether the brick possesses to a sufficient degree, strength, toughness, and hardness].

Section 5.—Change from its present form: namely,

> The percentage of loss in the rattler test to be taken as the standard is not fixed in these specifications, and shall remain within the province of the contracting parties. For their information, the average percentage of loss as determined in accordance with the rattler test in the Tentative Methods of Testing Brick (Serial Designation: C 67 - 27 T) of the American Society for Testing Materials, should not exceed 22 per cent for heavy-traffic brick and 24 per cent for light-traffic brick.

to read as follows:

> The average percentage of loss when determined in accordance with the rattler test shall not exceed 22 per cent.

Add, as Sections 16 to 29, all matter dealing with the rattler test from the Tentative Methods of Testing Brick (C 67 - 27 T)[2] (Sections 13 to 26), revised by the omission of the note to the present Section 24 of the Methods, reading as follows:

> NOTE.—The percentage of loss to be taken as the standard remains within the province of the contracting parties. For their information, the average percentage of loss after correction as provided in Section 25 should not exceed 22 per cent for heavy traffic and 24 per cent for light traffic.

Tentative Methods of Testing Brick (C 67 - 27 T).[2]—

Section 1.—Omit the reference to the rattler test and add "The absorption test."

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[1] ***Proceedings***, **Am. Soc. Testing Mats., Vol. 27, Part I, p. 805 (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 248.**

[2] ***Proceedings***, **Am. Soc. Testing Mats., Vol. 27, Part I, p. 826 (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 269.**

Section 11. (b).—Change to read as follows by the addition of the italicized words and the omission of those in brackets:

A steel bearing piece [½ in. square] *¼ in. in thickness, 1½ in. in width* and of a length equal to the full width of the specimen shall be placed between the upper knife edge and the specimen.

Omit Sections 13 to 26, comprising the sections pertaining to the rattler test.

Add a new method for the determination of absorption, comprising Sections 13 to 18, to read as follows:

ABSORPTION TEST

Test Specimen

13. The test specimen shall be a whole brick.

14. The absorption test shall be made on at least five whole bricks.

Procedure

15. The sample shall be dried to constant weight at a temperature of 100 to 105° C. (212 to 221° F.).

16. When cool, the bricks shall be weighed separately on scales sensitive to within 0.5 per cent.

17. The dry bricks shall be totally immersed in soft, distilled or rain water at a temperature of 15.5 to 30.0° C. (60 to 86° F.) for five hours. The bricks shall then be removed, the surface water wiped off with a damp cloth and the bricks quickly weighed.

18. The percentage of absorption shall be calculated on the dry weight from the formula:

$$\text{Percentage of absorption} = \frac{100\,(b - a)}{a}$$

where a = weight of dry bricks; and
b = weight of saturated bricks.

Committee C-3, through its Sub-Committee XIII on Weathering and Porosity, has been actively considering the question of the resistance of brick to the action of weather. When the current Tentative Specifications for Building Brick (Made from Clay or Shale) (C 62 - 27 T) were prepared, it was the opinion of the committee that water absorption was not a reliable measure of resistance to weathering. Hence this test was eliminated. It was recognized that these specifications as they now stand are incomplete due to absence of any test for or classification based on resistance to weathering, so Sub-Committee XIII was charged with the formulation of a laboratory method of test for determination of resistance to weathering. For the present this study is limited to an investigation of the resistance of brick to frost action. A research program has been formulated and a section of Sub-Committee XIII has been appointed to investigate the feasibility of a joint-committee action as well as the matter of getting financial support from the industries.

As a matter of general information, Committee C-3 includes the following statement in this report:

There appears to be a widespread belief that the percentage of absorption of individual bricks is a governing factor in the ability of brick masonry to resist moisture penetration. It has been conclusively shown that such a belief is erroneous. On the contrary, a certain amount of absorption in the brick assists in obtaining a better bond between brick and mortar and therefore a more water-tight joint. Any water penetration in brick masonry undoubtedly passes largely through the mortar joint and not through the brick. This committee has always felt that if absorption percentage has any significance, it is as a possible measure of that quality of brick masonry known as durability.

In its report for 1927, the committee included as information, in order to elicit criticism, the following suggested definition for the term "brick":

> *Brick.*—A structural unit formed while plastic into a rectangular prism, usually solid and 8 by $3\frac{3}{4}$ by $2\frac{1}{4}$ in. in size.
>
> NOTE.—The term "brick" is understood to mean a unit of burned clay or shale. When other substances are used, such as lime and sand, cement and sand, fire clay, adobe, etc., the term "brick" should be suitably qualified.

The committee is now referring this definition to Committee E-8 on Nomenclature and Definitions for the development by that committee of a standard definition.

The present officers of the committee have been re-elected for the ensuing two years.

The recommendations appearing in this report have been submitted to letter ballot of the committee and 33 replies have been received. The results of the ballot are as follows:

Items	Affirmative	Negative	Not Voting
I. PROPOSED NEW TENTATIVE STANDARDS			
Tentative Specifications for Concrete Building Brick	26	4	3
Tentative Specifications for Sand-Lime Building Brick	27	3	3
II. REVISION OF TENTATIVE STANDARDS			
Tentative Specifications for Building Brick (Made from Clay or Shale) (C 62 - 27 T)	31	1	1
Tentative Specifications for Paving Brick (C 7 - 27 T)	26	3	4
Tentative Methods for Testing Brick (C 67 - 27 T)	26	4	3
III. WITHDRAWAL OF TENTATIVE STANDARD			
Tentative Specifications for Concrete Building Brick (C 55 - 24 T)	29	1	3

This report has been submitted to letter ballot of the committee, which consists of 41 members; 33 members returned their ballots, of whom 30 have voted affirmatively, 1 negatively, and 2 have marked their ballots "not voting."

Respectfully submitted on behalf of the committee,

T. R. LAWSON,
Chairman.

J. W. MCBURNEY,
Secretary

EDITORIAL NOTE

The proposed Specifications for Sand-Lime Building Brick were accepted for publication as tentative and appear on page 840.

The proposed Tentative Specifications for Concrete Building Brick were accepted as tentative to supersede the present tentative specifications, and appear on page 838.

The proposed revisions of the Tentative Specifications for Building Brick (Made from Clay or Shale) and for Paving Brick and of the Methods of Testing Brick were accepted. The tentative specifications and methods in their revised form appear on pages 836, 842 and 854, respectively.

REPORT OF COMMITTEE C-5
ON
FIRE TESTS OF MATERIALS AND CONSTRUCTION

Committee C-5 on Fire Tests of Materials and Construction desires to record its deep sorrow in the loss by death of its chairman, Ira H. Woolson, who served in that capacity since the organization of the committee twenty-five years ago. Mr. Woolson was an outstanding figure in the field of fire prevention. With his wide experience in the investigation and testing of materials of construction and their assembly into structures designed to resist the destructive effects of fire, he led the work of this committee with impartiality and efficiency, made pleasant and delightful, especially to his associates on the committee, by a genial personality.

During the fall of 1927, the Secretary of the Society notified the committee that the Executive Committee had acted on the recommendation made in a paper presented by Messrs. Dunlap and Cartwright at the 1927 annual meeting, and referred to Committee C-5 for consideration the preparation of specifications governing fire tests to determine the fire resistance of combustible materials, both natural and treated to render them more fire resistant.

A meeting of Committee C-5 was held at the rooms of the American Society of Civil Engineers, New York City, on December 19, 1927, for the discussion of this matter and the formulation of a procedure to carry into effect the recommendation made. After considerable discussion, the committee decided that for the present any investigation and suggestions for tests shall be limited to lumber, both natural and treated by any process to render it more fire resistant, and shall not include other combustible materials that might be utilized in building construction. The investigation is not to be limited to the preparation of methods appropriate for tests of materials treated by any one specified process, but will include test methods applicable to untreated lumber as well as to lumber treated by impregnation, surface application, or other means of diminishing the fire hazard of the natural material. The fire tests that are to be developed are to apply to materials that enter into the finish of buildings and are not to apply to elements of a building or structure on which the stability of such building or structure is dependent. The present Tentative

Specifications for Fire Tests of Building Construction and Materials (C 19 – 26 T) are applicable to materials used for structural elements.

The investigation and formulation of suitable tests is now being considered by a sub-committee of Committee C-5. The work of the sub-committee has, however, not developed sufficiently to make a report possible.

The suggestion has been made to Committee C-5 that the present Tentative Specifications for Fire Tests of Building Construction and Materials (C 19 – 26 T) be recommended for advancement to standard. From correspondence with the secretary of the Sectional Committee on Fire Tests of Materials and Construction functioning under the procedure of the American Engineering Standards Committee, it appears that some criticisms and suggestions have been received by that Sectional Committee of the tentative specifications which it was deemed should have consideration of the Sectional Committee as well as Committee C-5 before any further recommendation with regard to the tentative specifications is made. It was felt that further experience with the standard fire test was desirable before recommending its advancement to full standard.

The committee has elected the following officers to serve for the ensuing two years: Rudolph P. Miller, chairman; Fitzhugh Taylor, secretary.

This report has been submitted to letter ballot of the committee, which consists of 14 members; 13 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

RUDOLPH P. MILLER,
Chairman.

FITZHUGH TAYLOR,
Secretary.

REPORT OF COMMITTEE C-6
ON
DRAIN TILE

Some members of the committee attended one special conference and the committee has held one regular meeting since the last meeting of the Society.

On November 16, 1927, Secretary Warwick, representing the Executive Committee, and Anson Marston, chairman of Committee C-6 met in Chicago with representatives of the two materials interests for a discussion of questions relative to the proposed new committee which would combine and extend the work of Committee C-6 and Committee C-4 on Clay and Cement-Concrete Pipe.

The committee held a regular meeting in Chicago on March 19, 1928, with eight members present. After receiving reports of research work under way, the committee recommended that this work be continued and that a study of the loads upon conduits in trenches which, at the level of the top of the pipe, are considerably wider than the outside diameter of the pipe, be undertaken.

The committee regrets the resignation of Mr. G. W. Pickels, who has served as its secretary. Mr. R. W. Crum was elected to fill the vacancy created by Mr. Pickels' resignation.

The following were elected as officers of the committee for the next two years:

Anson Marston, chairman
W. J. Schlick, secretary
D. A. Abrams, assistant secretary

This report has been submitted to letter ballot of the committee, which consists of 19 members; 14 members returned their ballots, all of whom have voted affirmatively.

Anson Marston,
Chairman.

W. J. Schlick,
Secretary.

REPORT OF SOCIETY REPRESENTATIVES ON THE JOINT CONCRETE CULVERT PIPE COMMITTEE

The Joint Concrete Culvert Pipe Committee, organized in 1919, consists of two representatives from each of the following:

- American Association of State Highway Officials;
- American Concrete Institute;
- American Concrete Pipe Association;
- American Railway Engineering Association;
- American Society of Civil Engineers;
- American Society for Testing Materials;
- Bureau of Public Roads, U. S. Department of Agriculture.

The Joint Committee is now submitting the "Proposed Tentative Specifications for Reinforced Concrete Culvert Pipe," appended hereto, to each of the constituent organizations as a "Second Report" of the committee. This report contains a foreword giving a brief statement of the organization of the committee and its work, and the bases for the several provisions of the specifications.

The committee issued a first draft of the specifications in 1926, and since then has secured additional data which form the bases for a slight increase in the test and design load requirements for "Extra-Strength Reinforced Concrete Culvert Pipe," a slight decrease in the specified amounts of circumferential reinforcement, and the inclusion of an absorption test.

The Society's representatives recommend that the appended specifications be approved as tentative by the Society, and that the Society continue its representation on the Joint Committee.

Respectfully submitted,

Anson Marston,
Asa E. Phillips,
A.S.T.M. Representatives,
Joint Concrete Culvert Pipe Committee.

Editorial Note

The proposed Tentative Specifications for Reinforced Concrete Culvert Pipe were received at the annual meeting and were referred to the Executive Committee of the Society.

SECOND REPORT OF THE JOINT CONCRETE CULVERT PIPE COMMITTEE

Submitting Proposed Tentative Specifications for Reinforced Concrete Culvert Pipe

The Joint Concrete Culvert Pipe Committee was organized in 1919 to prepare standard specifications for reinforced-concrete pipe to be used for railway and highway culverts. The committee has held one or more meetings each year since its organization and in February, 1926, it presented to the constituent organizations a report embodying recommended tentative specifications for reinforced-concrete culvert pipe. That report was very widely distributed, more than 5000 copies being furnished to public officials and manufacturers and users of pipe in the United States and Canada.

At the outset the committee found that there was little known with reference to the actual loads to which culverts are subjected. An investigation of this subject had been inaugurated at Iowa State College under the direction of Dean Anson Marston. The committee encouraged the vigorous prosecution of that work so that the results could be used in connection with the development of the specifications for culvert pipe. One meeting of the committee was held at Ames at which time the research under way was reviewed and the whole problem of loads was given extended consideration. At later times, two progress reports on the Ames investigation were submitted to the committee. The data included were of great value in connection with the determination of the loads for which culvert pipe should be designed.

A considerable amount of data from tests of pipe and from experience in the use of pipe were furnished by members of the committee and by manufacturers of pipe and engineers who had installed pipe or observed its behavior in embankments. All of this material was considered by the committee when the first tentative specifications were being prepared.

After the 1926 specifications were distributed the committee accumulated evidence indicating that pipe could be produced to meet the strength requirements with less circumferential reinforcement than was prescribed by the specifications. Accordingly, the committee arranged for a series of tests to be made under the direction of W. J. Schlick, Drainage Engineer, Iowa Engineering Experiment

Station, for the purpose of securing information with reference to this subject. Pipe with various amounts of circumferential reinforcement and made of concrete of various strengths, were made and tested under the direction of Mr. Schlick in eight pipe plants in the United States. There were 167 standard sections ranging from 12 to 60 in. in diameter. These tests showed that pipe of the specified strengths could be made with less circumferential reinforcement than was required by the 1926 specifications.

Meanwhile there had developed a demand for the inclusion of an absorption requirement and in 1927 the committee arranged for Mr. Schlick to test for absorption specimens of concrete pipe furnished by manufacturers in various parts of the United States.

Copies of the reports on the two series of tests may be obtained from the Secretary of the American Concrete Pipe Association, 33 W. Grand Avenue, Chicago, Ill.

The information secured from the tests and the additional facts that have been developed with reference to loads subsequent to the previous reports were the basis of the accompanying revision of the 1926 specifications. The principal revisions are in the amount of circumferential reinforcement, the load requirement for Extra-Strength Pipe and the inclusion of an absorption test.

The moment formula given in the section on design is essentially the one developed years ago for an elastic ring under opposed external forces. A discussion of this theory was presented by Prof. A. N. Talbot of the University of Illinois in *Bulletin 22* of the Illinois Engineering Experiment Station entitled, "Tests of Cast-Iron and Reinforced-Concrete Culvert Pipe."

Early in its deliberations the committee decided that, while culvert pipe may be used under many conditions of loading, it is feasible to meet all ordinary commercial needs with two stock, or standard, classes of pipe. The formulas for design provide a means of designing pipe to meet any special condition of loading for which standard pipe are not adapted.

The assumptions as to load for the two classes of pipe have been correlated with the strength test requirements and were adopted after considering the results of strength tests of pipe and measurements of actual loads on pipe.

The work of the committee was greatly facilitated by the cordial cooperation of manufacturers of culvert pipe. The industry assisted the committee in many ways and several manufacturers furnished pipe for testing and facilities at their plants for making the required tests.

It is the recommendation of this committee that the specifications submitted herewith be adopted by each constituent organization as tentative specifications for reinforced-concrete culvert pipe, superseding those reported in February, 1926.

PERSONNEL OF JOINT COMMITTEE

The personnel of the Joint Committee is as follows:

American Society for Testing Materials

Dean Anson Marston (Chairman), Iowa State College, Ames, Iowa.

A. E. Phillips, Consulting Engineer, 2400 Wyoming Avenue N. W., Washington, D. C.

Bureau of Public Roads

T. H. MacDonald, Chief, Bureau of Public Roads, Department of Agriculture, Washington, D. C.

A. T. Goldbeck, Director, Bureau of Engineering, National Crushed Stone Association, 751 Earle Building, Washington, D. C. (Formerly Chief of Tests, Bureau of Public Roads, Washington, D. C. Resigned, 1926.)

E. F. Kelley, Chief, Division of Tests, Bureau of Public Roads, Department of Agriculture, Washington, D. C. (Succeeded A. T. Goldbeck, 1926.)

American Society of Civil Engineers

George H. Tinker, Bridge Engineer, N. Y., C. & St. L. Ry., 926 Terminal Tower Bldg., Cleveland, Ohio.

T. L. D. Hadwen, Asst. Engr., C., M., St. P. & P. Ry., 898 Union Station, Chicago, Ill.

American Association of State Highway Officials

T. R. Agg, Professor of Highway Engineering, Iowa State College, Ames, Iowa.

J. N. Mackall, Chairman, Maryland State Roads Commission, Garrett Building, Baltimore, Md.

American Railway Engineering Association

Job Tuthill, Asst. Chief Engineer, Pere Marquette Railway, Fort Street Depot, Detroit, Mich.

A. F. Robinson, Bridge Engineer, A., T. & S. F. Ry., Railway Exchange Building, Chicago, Ill. (Resigned, 1925.)

G. A. Haggander, Bridge Engineer, C., B. & Q. R. R., 547 W. Jackson Blvd., Chicago, Ill. (Succeeded A. F. Robinson, 1925.)

American Concrete Institute

B. S. Pease, Manager, Reinforcing Department, American Steel and Wire Co., 208 S. LaSalle St., Chicago, Ill.

A. B. Cohen, Consulting Engineer, 1 Madison Ave., New York, N. Y. (Resigned, 1926.)

F. F. Longley, Lock Joint Pipe Co., Ampere, N. J. (Succeeded A. B. Cohen, 1926.)

American Concrete Pipe Association

Paul Kircher, Vice President, Canadian Concrete Products Co., Ltd., 312 Transportation Bldg., Montreal, P. Q., Canada.

W. H. Robertson, Massey Concrete Products Corp., Hudson Terminal Bldg., 50 Church St., New York, N. Y. (Succeeded the late Paul Kircher, 1927.)

C. F. Buente, Secretary, Concrete Products Company of America, Diamond Bank Building, Pittsburgh, Pa.

Respectfully submitted,

M. W. LOVING,
Secretary.

APPENDIX

PROPOSED TENTATIVE SPECIFICATIONS FOR REINFORCED CONCRETE CULVERT PIPE

GENERAL

Scope. 1. These specifications cover reinforced concrete pipe intended to be used for the construction of culverts.

Classes. 2. Pipe, under these specifications, shall be of two classes known respectively as "Standard Reinforced Concrete Culvert Pipe" and "Extra Strength Reinforced Concrete Culvert Pipe."

Basis of Acceptance. 3. The acceptability of pipe shall be determined by the results of the strength and absorption tests hereinafter specified, if and when required, and by inspection to determine whether the pipe comply with the specifications as to design, and freedom from defects.

MATERIALS

Reinforced Concrete. 4. The reinforced concrete shall consist of portland cement, mineral aggregate and water in which steel has been embedded in such a manner that the steel and the concrete act together in resisting forces.

Cement. 5. Portland cement shall meet the requirements of the current Standard Specifications and Tests for Portland Cement of the American Society for Testing Materials.

Steel. 6. Reinforcement may consist either of wire which meets the requirements of the current Specifications for Cold-Drawn Steel Wire for Concrete Reinforcement or of bars which meet the requirements of the current Standard Specifications for Billet-Steel Concrete Reinforcement Bars of the American Society for Testing Materials.

Fine Aggregate. 7. (*a*) Fine aggregate shall consist of sand, stone screenings, or other inert materials with similar characteristics, or a combination thereof, having clean, hard, strong, durable, uncoated grains and free from injurious amounts of dust, lumps, soft or flaky particles, shale, alkali, organic matter, loam or other deleterious substances. Fine aggregate shall be well graded and shall pass a ¼-in. screen.

Coarse Aggregate. (*b*) Coarse aggregate shall consist of crushed stone, gravel, slag, or other approved inert materials with similar characteristics, or combinations thereof, having clean, hard, strong, durable, uncoated particles, free from injurious amounts of soft, friable, thin, elongated or laminated pieces, alkali, organic or other deleterious matter.

Mixture. 8. The aggregates shall be so graded and proportioned and thoroughly mixed with such a proportion of cement and water as will produce a homogeneous concrete mixture of such quality that the concrete will meet the test and design requirements herein specified.

TABLE I.—DESIGN DATA FOR STANDARD REINFORCED CONCRETE CULVERT PIPE.

Internal Diameter d of Pipe, in.	Minimum Thickness of Shell, in.	Minimum Distance t Center of Reinforcement to Compressive Surface, in.		Minimum Area A of Circumferential Reinforcement, sq. in. per linear foot of pipe			
				Cold-Drawn Steel Wire $f_s = 27\,500$ lb. per sq. in.		Billet-Steel Hard and Intermediate Grades $f_s = 20\,000$ lb. per sq. in.	
		Circular Reinforcement in Circular Pipe	Elliptical Reinforcement in Circular Pipe and Circular Reinforcement in Elliptical Pipe	Circular Reinforcement in Circular Pipe	Elliptical Reinforcement in Circular Pipe and Circular Reinforcement in Elliptical Pipe	Circular Reinforcement in Circular Pipe	Elliptical Reinforcement in Circular Pipe and Circular Reinforcement in Elliptical Pipe
Uniform Load of 2000 lb. per sq. ft.; Ultimate Compressive Strength of Concrete, 2750 lb. per sq. in ; $f_c = 1030$ lb. per sq. in.							
12	2	1	..	1 Line 0.07	....	1 Line 0.09	....
15	$2\frac{1}{4}$	$1\frac{1}{8}$	$1\frac{1}{4}$	1 " 0.09	1 Line 0.08	1 " 0.13	1 Line 0.12
18	$2\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{1}{2}$	1 " 0.12	1 " 0.10	1 " 0.17	1 " 0.14
24	3	$1\frac{1}{2}$	2	1 " 0.17	1 " 0.13	1 " 0.25	1 " 0.19
30	$3\frac{1}{2}$	$1\frac{3}{4}$	$2\frac{1}{2}$	1 " 0.23	1 " 0.17	1 " 0.32	1 " 0.23
30	$3\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{1}{2}$	2 " each 0.17	1 " 0.17	2 " each 0.23	1 " 0.23
36	4	3	3	2 " " 0.20	1 " 0.20	2 " " 0.28	1 " 0.28
42	$4\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{2}$	2 " " 0.23	1 " 0.23	2 " " 0.32	1 " 0.32
48	5	4	4	2 " " 0.26	1 " 0.26	2 " " 0.37	1 " 0.37
54	$5\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{1}{2}$	2 " " 0.30	1 " 0.30	2 " " 0.42	1 " 0.42
60	6	5	5	2 " " 0.33	1 " 0.33	2 " " 0.46	1 " 0.46
72	7	6	6	2 " " 0.40	1 " 0.40	2 " " 0.56	1 " 0.56
84	8	7	7	2 " " 0.46	1 " 0.46	2 " " 0.65	1 " 0.65
Uniform Load of 2000 lb. per sq. ft.; Ultimate Compressive Strength of Concrete, 4000 lb. per sq. in.; $f_c = 1500$ lb. per sq. in.							
12	$1\frac{3}{4}$	$\frac{7}{8}$	..	1 Line 0.08	....	1 Line 0.11	....
15	2	1	..	1 " 0.11	....	1 " 0.15	....
18	$2\frac{1}{4}$	$1\frac{1}{8}$	$1\frac{1}{4}$	1 " 0.14	1 Line 0.12	1 " 0.19	1 Line 0.17
24	$2\frac{5}{8}$	$1\frac{1}{4}$	$1\frac{5}{8}$	1 " 0.21	1 " 0.17	1 " 0.30	1 " 0.23
30	3	$1\frac{1}{2}$	2	1 " 0.29	1 " 0.21	1 " 0.38	1 " 0.29
30	3	2	2	2 " each 0.21	1 " 0.21	2 " each 0.29	1 " 0.29
36	$3\frac{3}{8}$	$2\frac{3}{8}$	$2\frac{3}{8}$	2 " " 0.26	1 " 0.26	2 " " 0.36	1 " 0.36
42	$3\frac{3}{4}$	$2\frac{3}{4}$	$2\frac{3}{4}$	2 " " 0.30	1 " 0.30	2 " " 0.41	1 " 0.41
48	$4\frac{1}{4}$	$3\frac{1}{4}$	$3\frac{1}{4}$	2 " " 0.34	1 " 0.34	2 " " 0.46	1 " 0.46
54	$4\frac{5}{8}$	$3\frac{5}{8}$	$3\frac{5}{8}$	2 " " 0.38	1 " 0.38	2 " " 0.52	1 " 0.52
60	5	4	4	2 " " 0.42	1 " 0.42	2 " " 0.59	1 " 0.59
72	$5\frac{3}{4}$	$4\frac{3}{4}$	$4\frac{3}{4}$	2 " " 0.51	1 " 0.51	2 " " 0.71	1 " 0.71
84	$6\frac{5}{8}$	$5\frac{5}{8}$	$5\frac{5}{8}$	2 " " 0.60	1 " 0.60	2 " " 0.82	1 " 0.82

TABLE II.—DESIGN DATA FOR EXTRA-STRENGTH REINFORCED CONCRETE CULVERT PIPE.

Internal Diameter d of Pipe, in.	Minimum Thickness of Shell, in.	Minimum Distance t Center of Reinforcement to Compressive Surface, in.		Minimum Area A of Circumferential Reinforcement, sq. in. per linear foot of pipe			
				Cold-Drawn Steel Wire $f_s = 27\,500$ lb. per sq. in.		Billet-Steel Hard and Intermediate Grades $f_s = 20\,000$ lb. per sq. in.	
		Circular Reinforcement in Circular Pipe	Elliptical Reinforcement in Circular Pipe and Circular Reinforcement in Elliptical Pipe	Circular Reinforcement in Circular Pipe	Elliptical Reinforcement in Circular Pipe and Circular Reinforcement in Elliptical Pipe	Circular Reinforcement in Circular Pipe	Elliptical Reinforcement in Circular Pipe and Circular Reinforcement in Elliptical Pipe
UNIFORM LOAD OF 4000 LB. PER SQ. FT.; ULTIMATE COMPRESSIVE STRENGTH OF CONCRETE, 2750 LB. PER SQ. IN. $f_c = 1030$ lb. per sq. in.							
12	$2\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{1}{2}$	1 Line 0.11	1 Line 0.09	1 Line 0.15	1 Line 0.13
15	$2\frac{3}{4}$	$1\frac{3}{8}$	$1\frac{3}{4}$	1 " 0.15	1 " 0.12	1 " 0.21	1 " 0.17
18	$3\frac{1}{8}$	$1\frac{5}{8}$	$2\frac{1}{8}$	1 " 0.18	1 " 0.14	1 " 0.26	1 " 0.20
24	$3\frac{7}{8}$	2	$2\frac{7}{8}$	1 " 0.26	1 " 0.19	1 " 0.37	1 " 0.27
30	$4\frac{5}{8}$	$2\frac{1}{4}$	$3\frac{5}{8}$	1 " 0.36	1 " 0.23	1 " 0.51	1 " 0.33
30	$4\frac{5}{8}$	$3\frac{5}{8}$	$3\frac{5}{8}$	2 " each 0.23	1 " 0.23	2 " each 0.33	1 " 0.33
36	$5\frac{3}{8}$	$4\frac{3}{8}$	$4\frac{3}{8}$	2 " " 0.28	1 " 0.28	2 " " 0.40	1 " 0.40
42	6	5	5	2 " " 0.33	1 " 0.33	2 " " 0.47	1 " 0.47
48	$6\frac{3}{4}$	$5\frac{3}{4}$	$5\frac{3}{4}$	2 " " 0.38	1 " 0.38	2 " " 0.53	1 " 0.53
54	$7\frac{1}{2}$	$6\frac{1}{2}$	$6\frac{1}{2}$	2 " " 0.42	1 " 0.42	2 " " 0.60	1 " 0.60
60	$8\frac{1}{4}$	$7\frac{1}{4}$	$7\frac{1}{4}$	2 " " 0.47	1 " 0.47	2 " " 0.66	1 " 0.66
72	$9\frac{5}{8}$	$8\frac{5}{8}$	$8\frac{5}{8}$	2 " " 0.57	1 " 0.57	2 " " 0.80	1 " 0.80
84	11	10	10	2 " " 0.67	1 " 0.67	2 " " 0.94	1 " 0.94
UNIFORM LOAD OF 4000 LB. PER SQ. FT.; ULTIMATE COMPRESSIVE STRENGTH OF CONCRETE, 4750 LB. PER SQ. IN. $f_c = 1780$ lb. per sq. in.							
12	2	1	..	1 Line 0.14	....	1 Line 0.19	....
15	$2\frac{1}{4}$	$1\frac{1}{8}$	$1\frac{1}{4}$	1 " 0.19	1 Line 0.17	1 " 0.26	1 Line 0.24
18	$2\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{1}{2}$	1 " 0.24	1 " 0.21	1 " 0.34	1 " 0.29
24	3	$1\frac{1}{2}$	2	1 " 0.35	1 " 0.27	1 " 0.50	1 " 0.39
30	$3\frac{1}{2}$	$1\frac{3}{4}$	$2\frac{1}{2}$	1 " 0.47	1 " 0.34	1 " 0.66	1 " 0.48
30	$3\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{1}{2}$	2 " each 0.34	1 " 0.34	2 " each 0.48	1 " 0.48
36	4	3	3	2 " " 0.41	1 " 0.41	2 " " 0.57	1 " 0.57
42	$4\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{2}$	2 " " 0.48	1 " 0.48	2 " " 0.67	1 " 0.67
48	5	4	4	2 " " 0.55	1 " 0.55	2 " " 0.76	1 " 0.76
54	$5\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{1}{2}$	2 " " 0.62	1 " 0.62	2 " " 0.86	1 " 0.86
60	6	5	5	2 " " 0.68	1 " 0.68	2 " " 0.95	1 " 0.95
72	7	6	6	2 " " 0.82	1 " 0.82	2 " " 1.14	1 " 1.14
84	8	7	7	2 " " 0.96	1 " 0.96	2 " " 1.33	1 " 1.33

DESIGN

Methods of Design. 9. The pipe shall be designed in accordance with the following assumptions:

(*a*) That the design load is equivalent to a vertical load uniformly distributed over the internal horizontal projection of the pipe, that the pipe is likewise uniformly supported and that no allowance is made for side pressure.

(*b*) The uniform load for the "Standard Reinforced Concrete Culvert Pipe" shall be 2000 lb. per sq. ft. and for the "Extra Strength Reinforced Concrete Culvert Pipe" 4000 lb. per sq. ft., respectively.

(*c*) The working stress per square inch in compression for the concrete shall not exceed three-eighths of the strength of concrete upon which the design is based.

(*d*) The ratio, n, of the modulus of elasticity of steel to that of concrete shall be 12 for concrete having an ultimate compressive strength at 28 days of 2750 lb. per sq. in. and 9 for concrete having an ultimate compressive strength of 4000 lb. per sq. in. or greater. Intermediate values of n shall be proportional to the strength of concrete assumed in the design.

(*e*) The working stress for cold-drawn steel wire shall not exceed 27,500 lb. per sq. in. For billet-steel, intermediate and hard grades, the working stress shall not exceed 20,000 lb. per sq. in.; and for billet-steel, structural grade, the working stress shall not exceed 18,000 lb. per sq. in.

(*f*) The distance from the center of the reinforcement to the nearest or tension surface of the concrete shall not be less than $\frac{3}{4}$ in. for pipe 12 in. or less in diameter, or less than 1 in. for pipe more than 12 in. in diameter.

(*g*) The distance from the center of the tension reinforcement to the compression surface of the concrete and the area of the reinforcement shall not be less than that required by the formula·

$$\frac{wd}{16} \times \frac{d+t}{12} = jAtf_s$$

where w = uniform vertical load in pounds per square foot top and bottom of pipe;
d = internal diameter of pipe in inches;
t = distance from the center of the tension reinforcement to the compression surface of the concrete in inches;
A = sectional area of tension reinforcement in square inches per linear foot of the pipe;
f_s = tensile stress in the reinforcement in pounds per square inch;
j = ratio of the lever arm of the reinforcement to t as determined by the usual formulas.

Minimum Designs. 10. The shell thickness and the amount of circumferential reinforcement shall not be less than that given in the design tables for the classes and sizes of pipe and the strength of concrete therein specified.

Alternative Designs. 11. Manufacturers may submit to the consumer or purchaser, for approval, designs based on strengths of concrete other than those given in the design tables. Such alternate designs shall comply with the design requirements given in Sections 9 and 10 of these specifications. In no alternative design, however, shall the shell thicknesses be less than those given in the lower half of Table I, nor shall the strength of concrete be less than that given in the upper half of Table I.

Standard Sizes. 12. Pipe of the internal diameters listed in the design tables shall be considered standard sizes for culvert construction. In elliptical pipe, the inside diameter at the minor axis shall be equal to the diameter of the corresponding size of circular pipe.

Joints. 13. The ends of the pipe shall be of such design that the pipe when laid shall make a continuous conduit with a smooth and uniform interior surface.

Placing Reinforcement. 14. When a single line of circular reinforcement is used in circular pipe, it shall be placed at the center of the pipe shell. When two lines of reinforcement are used in circular pipe, one shall be placed near the inner and one near the outer surface of the pipe. The single line of elliptical reinforcement used in circular pipe, or the single line of circular reinforcement in elliptical pipe shall be placed near the inner surface at the "top" and "bottom" of the pipe and near the outer surface at the sides (see Section 20 (*d*)).

Longitudinals. 15. Each line of circumferential reinforcement shall be assembled into a cage and have sufficient longitudinal bars or members, extending through the barrel of the pipe, to afford rigidity and maintain the reinforcement in exact shape and correct position within the form.

Laps and Welds. 16. The reinforcement shall be lapped not less than 30 diameters, or if welded, the joints shall develop the full strength of the reinforcement. The spacing center to center of adjacent rings of circumferential reinforcement in a cage shall not exceed 4 in. up to and including pipe 48 in. in diameter, nor exceed the shell thickness for larger pipe and shall in no case exceed 6 in.

Bell Reinforcement. 17. The bell shall have a circumferential reinforcement equal in unit area to that of a single line within the barrel of the pipe.

WORKMANSHIP AND FINISH

Finish. 18. Pipe shall be substantially free from fractures, large or deep cracks and surface roughness. The planes of the ends of the pipe shall be perpendicular to their longitudinal axes.

Variations in Dimensions. 19. (*a*) Variations of the internal diameter shall not exceed 1.5 per cent nor shall the shell thickness be less than that intended in the design by more than 5 per cent at any point.

(*b*) Variation in the position of the reinforcement cages shall not exceed ¼ in. from the position provided in the design, nor shall the cover on the reinforcement be less than ¾ in. at any point.

MARKING

Marking. 20. The following shall be clearly stenciled on the pipe:

(*a*) The pipe class $\left\{\begin{array}{l}\text{by an } S \text{ for Standard Pipe; and}\\ \text{by an } X \text{ for Extra Strength Pipe;}\end{array}\right.$

(*b*) The date of manufacture;

(*c*) The name or trademark of manufacturer;

(*d*) Elliptical pipe with circular reinforcing and circular pipe with elliptical reinforcing shall have the words "Top or Bottom" clearly stenciled on the inside of the pipe at the correct place to indicate the proper position when laid.

PHYSICAL TESTS

(*A*) *Strength Test*

Strength Test. 21. Pipe may be tested for strength by either the three-edge-bearing or sand-bearing method:

Three-Edge-Bearing Test.

(*a*) *Three-Edge-Bearing.*—When the three-edge-bearing method is used, the lower bearing for the pipe shall consist of two wooden strips with vertical sides having their interior top corners rounded to a radius of approximately ½ in. The strips shall be straight and shall be securely fastened to a rigid block with the interior vertical sides spaced a distance apart not less than ½ in. nor more than 1 in. for each foot of diameter pipe. The upper bearing shall be a rigid wooden block, straight and true from end to end. The upper and lower bearings shall extend the full length of pipe exclusive of bell. The pipe shall be placed symmetrically between the two bearings as illustrated in Figs. 1 and 2. In testing pipe which is "out of line" the lines of the bearings chosen shall be from those which appear to give the most favorable conditions for fair test.

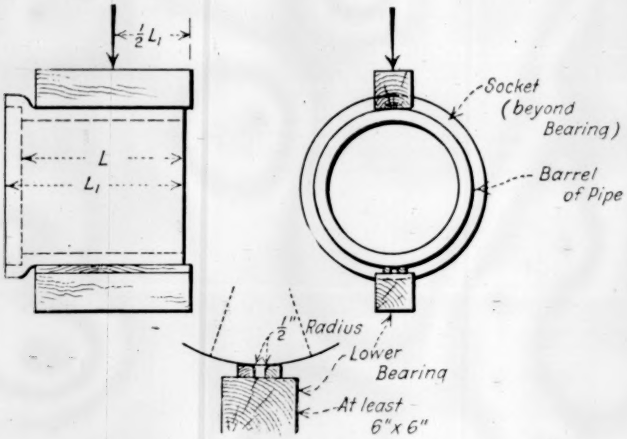

$\frac{1}{2}L_1$
L
L_1
Socket (beyond Bearing)
Barrel of Pipe
½" Radius
Lower Bearing
At least 6"x 6"

FIG. 1.

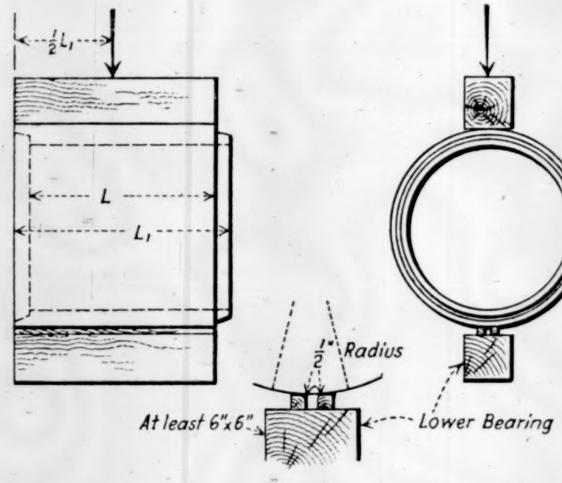
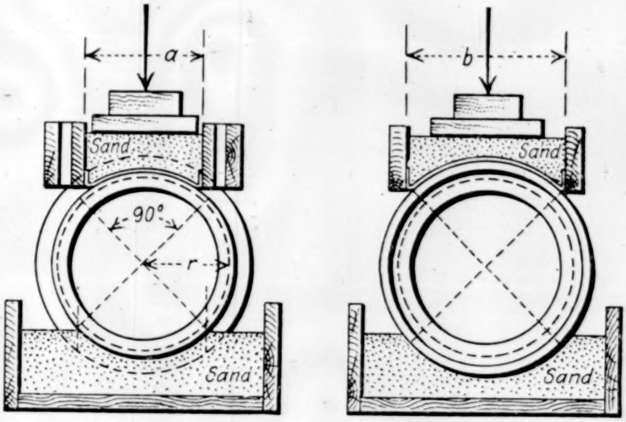

$\frac{1}{2}L_1$
L
L_1
½" Radius
At least 6"x 6"
Lower Bearing

FIG. 2.

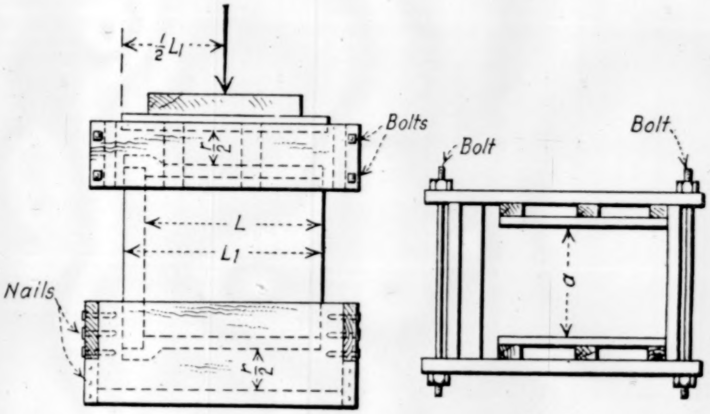
Sand-Bearing Test.

(*b*) *Sand-Bearing.*—When the sand-bearing method is used (see Figs. 3 and 4), the ends of each specimen of pipe shall be accurately marked prior to the test in quarters of the circumference. Specimens shall be carefully bedded, above and below, in sand, for one-fourth the circumference of the pipe measured on the middle line of the barrel. The depth of bedding above and below the pipe at the thinnest points shall be one-half the radius of the middle line of the barrel.



Bedding of Barrel.

Bedding of Socket.



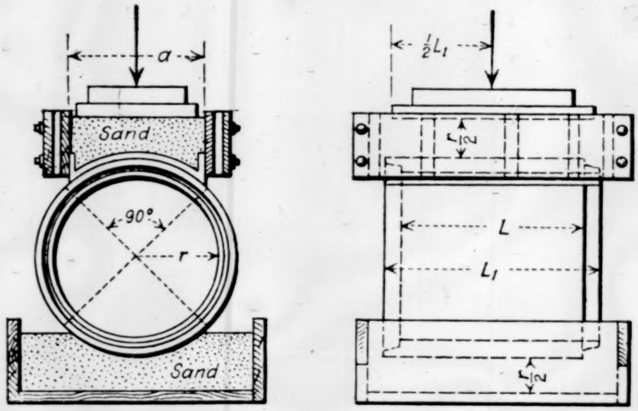
Side View.

Upper Bearing Frame.

FIG. 3.

The sand used shall be clean and moist, and shall be such as will pass a No. 4 (4760-micron) sieve.[1] The sand in the lower bearing shall be loose when the pipe is placed.

The top bearing frame shall not be allowed to come in contact with the pipe nor with the top bearing plate. The upper surface of the sand in the top bearing shall be struck level with a straight edge, and shall be covered with a rigid top bearing plate, with lower surface a true plane, made of heavy timbers or other rigid material, capable of distributing the test load uniformly without appreciable bending. The test load shall be applied at the exact center of this top bearing plate, or in such manner as to produce uniform deflection throughout the full length of the pipe. For this purpose a spherical bearing is preferred, but two rollers at right angles may be used. The test may be made without the use of a testing machine by piling weights directly on a platform resting on the top bearing plate, provided, however, that the weights shall be piled symmetrically about a vertical line through the center of the pipe, and that the platform shall not be allowed to touch the top bearing frame.



Bedding of Barrel.

FIG. 4.

The frames of the top and bottom bearings shall be made of timbers so heavy as to avoid appreciable bending by the side pressure of sand. The interior surfaces of the frames shall be dressed. No frame shall come in contact with the pipe during the test. A strip of cloth may, if desired, be attached to the inside of the upper frame on each side, along the lower edge, to prevent the escape of sand between the frame and the pipe.

Testing Apparatus. (*c*) It is desirable that a machine shall be used which gives a uniform deflection throughout the full length of the pipe. Any mechanical or hand power device may be used in which the head that applies the load moves at a speed of not more than 0.05 in. per minute while making the test. The testing machine shall be substantial and rigid throughout, so that the distribution of the load will not be affected appreciably by the deformation or yielding of any part. The load shall be applied continuously until the ultimate strength of the pipe is reached.

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[1] For requirements for this sieve see the Standard Specifications for Sieves for Testing Purposes (Serial Designation: E 11) of the American Society for Testing Materials, 1927 Book of A.S.T.M. Standards, Part II, p. 917.

Strength Requirements.

22. The ultimate load as determined by one of the methods described in Section 21 shall not be less than the ultimate load specified in Table III for the size and class of pipe that is being tested. When the test load reaches the cracking load specified in Table III for the size and class of pipe that is being tested, there shall be in the barrel of the pipe no crack having a surface width of 0.01 in. (see Note) or more, for a length of one foot or more. The ultimate load is reached when the pipe will sustain no greater load.

TABLE III.—MINIMUM STRENGTH OF REINFORCED CONCRETE CULVERT PIPE IN POUNDS PER FOOT OF LAYING LENGTH.

Size of Pipe, in.	Standard Reinforced Concrete Culvert Pipe				Extra-Strength Reinforced Concrete Culvert Pipe			
	3-Edge Bearing		Sand Bearing		3-Edge Bearing		Sand Bearing	
	Cracking Load[a]	Ultimate Load	Cracking Load[a]	Ultimate Load	Cracking Load[a]	Ultimate Load	Cracking Load[a]	Ultimate Load
12	1 600	2 000	2 400	3 000	3 200	4 000	4 800	6 000
15	1 800	2 500	2 700	3 750	3 600	5 000	5 400	7 500
18	2 000	3 000	3 000	4 500	4 000	6 000	6 000	9 000
24	2 200	4 000	3 300	6 000	4 400	8 000	6 600	12 000
30	2 500	5 000	3 750	7 500	5 000	10 000	7 500	15 000
36	3 000	6 000	4 500	9 000	6 000	12 000	9 000	18 000
42	3 500	7 000	5 250	10 500	7 000	14 000	10 500	21 500
48	4 000	8 000	6 000	12 000	8 000	16 000	12 000	24 000
54	4 500	9 000	6 750	13 500	9 000	18 000	13 500	27 000
60	5 000	10 000	7 500	15 000	10 000	20 000	15 000	30 000
72	6 000	12 000	9 000	18 000	12 000	24 000	18 000	36 000
84	7 000	14 000	10 500	21 000	14 000	28 000	21 000	42 000

[a] At the cracking load there shall be, in the barrel of the pipe, no crack having a surface width of 0.01 in. or more for a length of 1 ft. or more.

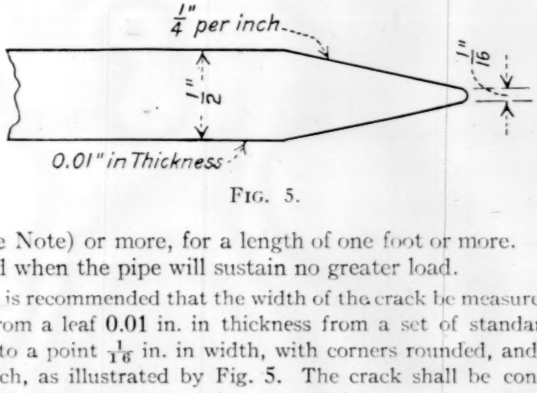

FIG. 5.

NOTE.—It is recommended that the width of the crack be measured by means of a gage made from a leaf 0.01 in. in thickness from a set of standard machinists' gages, ground to a point $\frac{1}{16}$ in. in width, with corners rounded, and with a taper of $\frac{1}{4}$ in. per inch, as illustrated by Fig. 5. The crack shall be considered to be 0.01 in. in width when the point of the gage will just enter it at close intervals.

Elliptical Pipe.

23. Elliptical pipe shall meet the test requirements for circular pipe having the same horizontal internal diameter.

Preliminary Tests and Tests for Extended Deliveries.

24. Preliminary to placing an order, a consumer of pipe whose needs require shipments at intervals over extended periods of time shall be entitled to test not more than ten pieces of pipe covering the size in which he is interested. The

test specimens shall be selected in approximately equal numbers from the larger and smaller sizes of pipe. The acceptability of the larger sizes of pipe shall not be based on the results of tests in smaller sizes. After these preliminary tests, a consumer shall be entitled to additional tests in such numbers and at such times as he may deem necessary, provided that the total number of pipe tested shall not exceed 2 per cent of the total deliveries.

Tests for Occasional Orders. 25. A purchaser who places occasional orders shall be entitled to test a number of pipe equal to 2 per cent of an order but not to exceed five pieces of any one size; otherwise the number of pipe desired for testing shall be included in the order.

Selecting Test Specimens. 26. (*a*) All pipe for testing purposes shall be selected at random by the consumer or purchaser from the stock of the manufacturer and shall be pipe which would not otherwise be rejected under these specifications. The pipe shall be free from visible moisture when tested.

(*b*) They shall not have been exposed to a temperature below 40° F. for the 24 hours immediately preceding the test.

Cylinder Tests and Reinforcement Examinations. 27. By agreement between the consumer and the manufacturer the continued acceptability of the pipe, after the preliminary pipe tests have been made, may be determined by tests of the quality of the concrete as placed in the pipe and examination of the quality, amount and the accuracy of placement of the reinforcement. The quality of the concrete shall be determined on 6 by 12-in. test cylinders taken from the concrete used in making the pipe and manufactured and cured under identical conditions with the pipe. When tested in accordance with the current standard methods prescribed by the American Society for Testing Materials, these cylinders shall have a strength not less than that assumed in the design of the pipe.

Retests. 28. Pipe shall be acceptable under the strength tests when all test specimens meet the test requirements. Should less than three of the ten preliminary test specimens or any one of the additional test specimens provided for in Section 24, or any one specimen provided for in Section 25 fail to meet the test requirements, then the manufacturer will be allowed a retest on two like specimens for each specimen that failed, and the pipe shall be acceptable only when all of these retest specimens meet the test requirements. No further retests shall be permitted.

(*B*) *Absorption Test*

Test Specimens. 29. Absorption tests shall be made by the following method:

(*a*) The number of absorption specimens shall be equal to the number of pipe provided for testing. The specimens shall be obtained from pipe that are acceptable as to strength and shall be taken from pipe used in making the strength test when that test is made. The specimens shall be marked with the number or identifying mark of the pipe from which they were taken. Each specimen shall have an area of 16 to 24 sq. in. and a thickness equal to the full depth of the pipe shell, and shall be free from visible cracks.

Drying Specimens. (*b*) Specimens shall be dried at a temperature of approximately 110° C. (230° F.) until no loss of weight is shown by successive weighings at intervals of not less than four hours.

Immersion and Reweighing. (*c*) The dried specimens shall be placed in a suitable receptacle, covered with distilled water or rain water, raised to the boiling point and boiled for five hours, and then cooled in water to a final temperature of from 15 to 20° C.

(59 to 68° F.). When cool, the specimens shall be removed from the water, allowed to drain for not more than one minute, the superficial water removed by a towel or blotting paper, and the specimens immediately weighed.

Weighing Devices. (*d*) The balance used shall be sensitive to 0.5 g. when loaded with 1 kg. and weighings shall be read at least to the nearest gram. Where other than metric weights are used, the same degree of accuracy must be obtained.

Calculation and Report. (*e*) The increase in weight of the boiled specimen over its dry weight shall be considered the absorption of the specimen and shall be calculated as a percentage of the dry weight. The results shall be reported separately for each specimen.

Test Requirements and Acceptability Under Absorption Tests. 30. The absorption shall not exceed 8 per cent for test specimens taken from pipe designed to be made of concrete having a compressive strength of 3000 lb. per sq. in. or more, or 9 per cent for test specimens taken from pipe designed to be made of concrete having a compressive strength of less than 3000 lb. per sq. in. Pipe shall be considered to meet these specifications for absorption when not less than 80 per cent of the number of specimens tested, including any retested, meet the test requirements. When the initial absorption specimen from a pipe fails to meet these specifications, the absorption test shall be made on another specimen from the same pipe and the results of the retest shall be substituted for the original test results.

Minimum Age for Shipment. 31. Pipe will be considered ready for shipment when they meet the test requirements, or when tests of 6 by 12-in. cylinders (Section 27) show that the concrete has attained the strength assumed in the design of the pipe.

Test Equipment. 32. Every manufacturer furnishing pipe under these specifications shall furnish all facilities necessary to carry out the tests herein provided.

INSPECTION

Inspection. 33. All materials, processes of manufacture and finished pipe shall be subject to inspection and approval by an inspector employed by the consumer or purchaser. The manufacturer when so directed by the inspector shall have holes cut in such sections of the finished pipe (not exceeding one hole in every 50 sections delivered) as desired so that a proper inspection may be made of the quantity and placement of the reinforcement. If the pipes are tested for strength or absorption, inspection of the reinforcement shall be made on the pipe used for those tests, and in no case shall the total number of pipe cut open for inspection of reinforcement exceed the number to which the purchaser is entitled under the provisions of Sections 24 or 25.

Causes for Rejection of Pipe. 34. Pipe shall be subject to rejection on account of failure to meet any of the specification requirements or on account of any of the following:

(*a*) Fractures or cracks passing through the shell, except that an end crack that does not exceed the depth of the joint, or a fracture that at its deepest point does not exceed the depth of the joint nor extend more than ten per cent around the circumference shall not be considered cause for rejection unless these defects exist in more than five per cent of the pipe inspected.

(*b*) Defects which indicate imperfect mixing and molding.

(*c*) Exposure of the reinforcement when such exposure would indicate that the reinforcement is misplaced.

REPORT OF COMMITTEE C-7

ON

LIME

Committee C-7 has held one meeting since the last annual meeting of the Society.

Sub-Committee V on Methods of Test recommends revisions of the method of measuring plasticity as described in the Standard Specifications for Hydrated Lime for Structural Purposes (C 6 – 24).[1] These revisions are necessary to reduce errors in plasticity measurement caused by relatively slight differences in the method of the preparation of the putty; by differences in the absorption of different lots of base plates; by different methods of cleaning and care of base plates; and to provide a standard method for measuring the absorption of base plates.

The revisions consist of the following:

Section 13.—Change the first paragraph to read as follows by the addition of the italicized words:

> 13. Plasticity shall be determined by means of the apparatus shown in Fig. 1 as follows: Three hundred grams of the sample shall be mixed with enough water to form a thick putty *and stirred vigorously for 3 minutes with a trowel or spatula.* After aging in a vessel covered with a damp cloth for not less than 16 nor more than 24 hours, this putty shall be *stirred vigorously for 3 minutes with a trowel or spatula and* adjusted to standard consistency, as defined in Section 12, with a permissible variation of ±5 mm.

Omit the last paragraph of this section reading as follows:

> After each test, the porcelain base plate shall be washed with hot water, treated with dilute hydrochloric acid to remove any lime from the surface pores, washed again with water, to remove the acid, dried by heating above 100° C., and cooled to room temperature before it is used again.

Add two new sections, numbered 14 and 15, to read as follows, renumbering the present Section 14 to read Section 16:

> 14. *Cleaning and Care of Base Plates.*—In making plasticity determinations much of the success attainable depends upon the condition of the base plates. Continued use of the plates without proper cleaning results in clogging of the pores, with reduction in the rate of absorption. After a plate has been used the excess lime shall be wiped off and the plate immersed in clear water for not less than two hours, after which it shall be transferred without drying to a

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 47.

dilute solution of hydrochloric acid (1:9) where it shall be kept immersed for another two hours. It should then be transferred to a receptacle containing running water for at least one hour. The plate is then free of acid and after the removal of excess water should be placed in an oven at a temperature of between 100 and 110°C. overnight for drying. Before using, the plate shall be cooled to room temperature.

15. *Absorption of Plasticimeter Base Plates.* (*a*) *Total Absorption.*—Plasticimeter base plates when immersed in water at room temperature for a period of 24 hours shall absorb not less than 40 g. of water. Before making the determination the plates shall be dried overnight in an oven at a temperature of between 100 and 110° C. and permitted to cool to room temperature. After immersion and before weighing, the excess water shall be wiped off with a damp cloth.

(*b*) *Rate of Absorption.*[a]—When tested over an area 2¾ in. in diameter the water absorbed shall be in accordance with the following:

	WATER ABSORBED, CC.
First Minute	8 to 14
Second Minute	5 to 7½
Third Minute	4 to 6½
Fourth Minute	4 to 6
Fifth Minute	3½ to 5½

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[a] A convenient apparatus for determining the rate of absorption consists of a burette sealed onto an inverted glass funnel from which the stem has been removed. The diameter of the larger end of the funnel shall be ground so as to be 2¾ in. in internal diameter. The funnel may be attached to the plate on which the measurement is being made by melted paraffin. The paraffin should not be too hot. A little experience will indicate when it is of the proper consistency.

Figure 1.—Revise the constants given under the illustration of the Emley Plasticimeter by changing the first line to read as follows:

Absorption of porcelain base plate.—Minimum 40 g. in 24 hours. For rate of absorption of base plates, see Section 15.

Tentative Definitions of Terms Relating to Lime (*C 51 - 24 T.*).[1]—The Tentative Definitions of Terms Relating to Lime have been tentative for two years, during which time no criticisms have been received. They are recommended to the Society for advancement to standard as given below, the definition for the term "in bulk" having been withdrawn:

Quicklime.—A calcined material, the major part of which is calcium oxide or calcium oxide in natural association with a lesser amount of magnesium oxide, capable of slaking with water.

Hydrated Lime.—A dry powder obtained by treating quicklime with water enough to satisfy its chemical affinity under the conditions of its hydration.

NOTE.—It consists essentially of calcium hydroxide or a mixture of calcium hydroxide and magnesium oxide and magnesium hydroxide.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 24, Part I, p. 848 (1924); also 1927 Book of A.S.T.M. Tentative Standards, p. 211.

Lump Lime.—Quicklime as it comes from the kilns.

Lump Lime Screened.—Lump lime after forking or screening to remove the finer portion.

NOTE.—The portion removed is usually that which will pass a ½-in. sieve.

Pulverized Lime.—Quicklime which will pass a fine sieve of specified size.

NOTE.—The size of the sieve is usually ¼ in.

The committee has elected the following officers to serve for the ensuing two years: H. C. Berry, chairman; E. E. Eakins, vice-chairman; J. M. Porter, vice-chairman; W. V. Brumbaugh, secretary.

The recommendations appearing in this report have been submitted to letter ballot vote of the committee with the following results

Items	Affirmative	Negative	Not Voting
I. REVISION OF STANDARDS.			
1. Revision of Standard Specifications for Hydrated Lime for Structural Purposes (C 6 - 24)	21	1	10
II. TENTATIVE DEFINITIONS ADVANCED TO STANDARD.			
2. Tentative Definitions of Terms Relating to Lime (C 51 - 24 T)	22	3	7

This report has been submitted to letter ballot of the committee, which consists of 32 members; 25 members returned their ballots, of whom 24 have voted affirmatively, 1 negatively, and none has marked his ballot "not voting."

Respectfully submitted on behalf of the committee,

H. C. BERRY,
Chairman.

W. V. BRUMBAUGH,
Secretary.

EDITORIAL NOTE

The proposed revisions of the Standard Specifications for Hydrated Lime for Structural Purposes were accepted for publication as tentative and appear on page 1121.

The Tentative Definitions of Terms Relating to Lime were approved at the annual meeting as revised by the committee, were subsequently adopted as standard by letter ballot of the Society on September 1, 1928, and appear in their revised form in the 1928 Supplement to Book of A.S.T.M. Standards.

REPORT OF COMMITTEE C-8
ON
REFRACTORIES

Committee C-8 held two meetings during the year subsequent to the annual meeting of the Society at French Lick, Ind., in June, 1927. The first meeting was held in Columbus, Ohio, in October at the Ohio State University and the second in February at Atlantic City, N. J., concurrently with the annual meeting of the American Ceramic Society.

The committee recommends for adoption as standard three tentative specifications for fire-clay brick and a list of tentative definitions of terms relating to refractories, as follows:

1. Tentative Specifications for Clay Fire Brick for Malleable Furnaces with Removable Bungs and for Annealing Ovens (C 63 - 27 T);[1]
2. Tentative Specifications for Clay Fire Brick for Stationary Boiler Service (C 64 - 27 T);[1]
3. Tentative Specifications for Clay Fire Brick for Marine Boiler Service (C 65 - 27 T);[1]
4. Tentative Definitions of Terms Relating to Refractories (C 71 - 27 T):[2]
    - (*a*) Fire Clay
    - (*b*) Plastic or Bond Fire Clay
    - (*c*) Flint Fire Clay
    - (*d*) Diaspore Clay
    - (*e*) Nodular Fire Clay

In respect to the Tentative Definitions of Terms Relating to Refractories it is proposed to include a definition for the term "fire clay." A definition for this term has already been adopted by the Society in connection with Definitions of Terms Relating to Hollow Tile (C 43) and in Specifications for Clay Sewer Pipe (C 13) and in Specifications for Drain Tile (C 4). The definition as appearing in these standards and as recommended for inclusion in the Definitions of Terms Relating to Refractories, is as follows:

Fire Clay.—A sedimentary clay of low flux content.

NOTE.—It is usually associated with coal measures.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, pp. 810–825 (1927); also 1927 Book of A.S.T.M. Tentative Standards. pp. 253–268.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 839 (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 282.

The definitions for the remaining terms mentioned above, modified slightly at the suggestion of Committee E-8 on Nomenclature and Definitions, and approved by that committee, are as follows:

Plastic or Bond Fire Clay.—A fire clay of sufficient natural plasticity to bond non-plastic materials.

Flint Fire Clay.—A hard or flint-like fire clay occurring as an unstratified massive rock, practically devoid of natural plasticity and showing a concoidal fracture.

Diaspore Clay.—A rock consisting essentially of diaspore bonded by fire clay.

Nodular Fire Clay.—A rock containing aluminous or ferruginous nodules, or both, bonded by fire clay.

NOTE.—In some districts such clays are called "burley" or "burley flint" clay.

The definition for the term "spalling" and for "pyrometric cone equivalent (P.C.E.)" are still under discussion with Committee E-8 and accordingly are being continued as tentative in their present form.

The committee further recommends for adoption as standard, tentative revisions in one method of test and in definitions of refractories: namely,

1. Standard Method of Test for Softening Point of Fire-Clay Brick (C 24 – 20);[1]
2. Standard Definitions for Clay Refractories (C 27 – 20).[2]

In respect to the tentative revision of the Standard Definitions of Clay Refractories (C 27 – 20) being recommended for adoption as standard, it is recommended that the centigrade temperature equivalents of the cones referred to be changed as follows:

Section 4.—Cone 31, Change from 1685° C. to read 1680° C.
Section 6.—Cone 29, Change from 1650° C. to read 1640° C.
Section 7.—Cone 28, Change from 1635° C. to read 1615° C.
Section 10.—Cone 28, Change from 1635° C. to read 1615° C.
Section 12.—Cone 26, Change from 1600° C. to read 1595° C.
Section 14.—Cone 19, Change from 1510° C. to read 1520° C.

In view of further possible changes in the spalling test, the committee recommends that the Tentative Method of Test for Resistance of Fire-Clay Brick to Thermal Spalling Action (C 38 – 27 T) be continued as tentative another year.

The Sub-Committee on Research has compiled the data obtained from a study under the direction of Mr. S. M. Phelps of Mellon Institute, of the reheat test in progress during the past year. This test was prompted by a feeling existant for some time that the test did not give results comparable with those obtained in service. In the present reheat test, brick are brought up to 1400° C. and held for 5 hours. In the more extended test the brick were exposed for 98 days in 3 different tunnel kilns in which the heat varied from about a minimum of cone 11 in one case to a maximum of cone 18. The data from the extended test indicate that the results obtained in the shorter test bear little relation to those obtained over long periods of time. This is more apparent from the "Volume Change" results taken from the very comprehensive data developed in the two tests and shown in Table I.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 1094 (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 768.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 1095 (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 769.

TABLE I.—RESULTS OF REHEAT TESTS ON REFRACTORIES, SHOWING COMPARISON OF LONG-TIME AND SHORT-TIME TESTS.

Sample		98-day Test, Volume Change	5-hour Test, at 1400° C., Volume Change, average of 2 brick
New Jersey siliceous clay brick	Kiln I[a]	+3.1 (1)[d]	......
	Kiln II[b]	+7.7 (4)	......
	Kiln III[c]	+5.3 (2)	+0.96
Pennsylvania clay brick	Kiln I	−4.7 (3)	......
	Kiln II	−7.7 (4)	......
	Kiln III	−6.9 (2)	+0.99
Kentucky clay brick	Kiln I	−1.4 (3)	......
	Kiln II	−2.1 (2)	......
	Kiln III	+1.8 (1)	+2.04
St. Louis high-grade clay brick	Kiln I	−0.6 (3)	......
	Kiln II	−0.9 (3)	......
	Kiln III	−2.1 (1)	+3.06
St. Louis high-alumina brick	Kiln I	−0.2 (3)	......
	Kiln II	+1.0 (4)	......
	Kiln III	−11.8 (2)	−1.20
Kentucky clay brick (edge-pressed)	Kiln I	−3.0 (2)	......
	Kiln II	−4.2 (3)	......
	Kiln III	−5.9 (1)	−3.06

[a] Tunnel kiln burning about cone 12, Missouri district.
[b] Tunnel kiln burning about cone 11, Western Pennsylvania district.
[c] Tunnel kiln burning about cone 17-18. Eastern Pennsylvania district.
[d] Numbers in parentheses indicate number of determinations used to arrive at figure shown for volume change.

It is planned to continue the study to develop information regarding the progress of the volume change.

Another project undertaken by the Sub-Committee on Research has been an investigation of the effect of the method of preparation of samples for pyrometric cone equivalent (P.C.E.) determination, and especially of certain refractory materials containing sodium silicate. This additative agent is known to segregate and migrate to the surface in drying. Eight typical cements, all containing sodium silicate, were selected. The P.C.E. values were determined under a variety of conditions as shown in Table II.

The above results indicate that in all cases the samples prepared from the raw cement, ground to pass a No. 60 sieve, using water and gum, are the lowest. Although there is considerable variation in the results, it seems that the raw material ground to 60-mesh and bonded with linseed oil gives a figure which should be quite suitable, and is about as high as any of those shown by the other means of preparation. Furthermore, this would be a simple way of conducting the test.

Additional work along this line is to be conducted, especially after receiving the information which will be obtained as a result of a questionnaire on cements used in boiler furnaces.

Considerable experimentation has also been in progress during the past year by the Sub-Committee on Research on the service spalling test in order to devise a procedure which would produce quantitative results and accordingly could be recommended to Committee C-8.

Table II.—Pyrometric Cone Equivalent of Refractory Cements, Containing Sodium Silicate.

	Gum Bond 60-mesh Unburned	Linseed Oil Bond 60-mesh Unburned	Linseed Oil Bond 100-mesh Unburned	Gum Bond 60-mesh Fired at 1100° C.	Gum Bond 60-mesh Fired at 1350° C.
Cement A	18–19	18	18	18	18
Cement B	4	5	12	5–6	10
Cement C	19	20–26	19–20	19	19–20
Cement D	20	20–26	20–26	20–26	20
Cement E	20–26	30	30–31	26–27	30–31
Cement F	16	20–26	20–26	20–26	20–26
Cement G	20	20–26	20–26	20–26	29 (?)
Cement H	18	18	20–26	20	20–26

The introduction of slag on the surface of the brick during preheating has been studied, but the results to date show that this does not increase the spalling tendency. The effect of preheating has also been studied in connection with the simulative service test. The brick were laid up in sections to form panels, and subsequently mounted in the service spalling furnace. These and other studies have produced sufficient information to warrant the construction of a new and improved spalling furnace. At the present time there is under construction equipment which it is believed can be recommended as an A.S.T.M. standard. The original testing equipment, although satisfactory in principle and operation, is not of the nature to be suggested as an A.S.T.M. standard.

It has been brought to the attention of Committee C-8 that there is a recognized demand on the part of consumers for some sort of standard testing procedure applicable to high-temperature cements and other jointing materials used in setting up fire brick. At the present time purchases are made largely by trade name and the user knows very little about the material which he is purchasing or its essential physical and chemical properties. In order to reduce to some order the rather chaotic condition existing in this particular field, the Sub-Committee on Industrial Survey has prepared a questionnaire dealing with refractory cements used in power plants and through the co-operation of Mr. C. F. Hirshfeld, chairman of the Special Research Committee on Boiler Furnace Refractories of the American Society of Mechanical Engineers, this questionnaire will be distributed to 200 power plant men. It is hoped that the results of the questionnaire will be of such a nature as to guide Committee C-8 in developing the proper test procedure for determining the relative merits of the materials in question.

A study of the sand-blast method at elevated temperatures as a quantitative measure of the resistance of refractories to abrasion has been actively in progress during the past year at the Physical Laboratory of the United Gas Improvement Co.

The apparatus used in this study consisted of a high-pressure container suspended from the cover down into a furnace. The incoming air passed through a coil of pipe, around the apparatus and located in the furnace, before entering the pressure chamber. The conditions were such that both the sand and the air were at the temperature of the furnace before they issued and impinged upon the brick under test, which lay in the bottom of the furnace.

With this apparatus it was found that two fire-clay bricks that were tested abraded very much less at high temperatures than they did at room temperatures. It was also found that this difference depended largely upon the P.C.E. value of the bricks used. To bring out this effect more prominently two bricks of widely differing P.C.E. values were selected. It was found that the brick with the lower P.C.E. value abraded relatively more at room temperature and relatively less at 1300° F. than did the other brick.

The work has not progressed far enough to draw any definite conclusions, beyond the fact that certain bricks might, and probably would, reverse their order of resistance to abrasion with change in temperature. This puts the whole question of the sand abrasion test in a position where it is of little value for anticipating the relative abrasion of bricks at elevated temperatures, unless the test is actually conducted at a high temperature.

Many modifying factors entered to make the work difficult; for example, the air at high temperatures has a very much higher velocity of exit, other things being equal, than at lower temperatures. Also the sand, which was in a separate container entirely within the pressure vessel, required for a given amount of sand 25 or 30 per cent more time to flow out under the hot condition than under the cold condition. This means a narrower stream of sand at a higher velocity. Furthermore, the apparatus deteriorates quite rapidly. A continuation of the work is planned to include a wider variety of types of refractories.

A new method better suited for the analysis of high-alumina refractories or some modification of the one in use at present which is valuable chiefly for the analysis of the usual fire-clay refractory, has been considered by the Section on Analysis. Several procedures have been suggested and one tried out in several laboratories. To date, however, the work has not progressed to the point where an acceptable procedure can be recommended as a substitute for the one in use.

The Standard Method of Test for Refractory Materials Under Load at High Temperatures (C 16 – 20) has been a matter of discussion and particularly with reference to some contention that as at present conducted it does not bring out differences in silica brick of different quality. This will involve further study by the committee to determine if any revisions are to be recommended.

A section has been organized under the direction of M. L. Hartmann to consider certain phases of heat transfer as related to refractory materials, since both the technical and trade literature on the thermal conductivity of refractories and heat insulation materials used in connection with refractories, is much confused and misleading. Further, there is no standard method of expressing conductivity nor is there any standard method for determining this important physical property of materials. It is proposed that this section consider:

1. Definitions of terms pertaining to heat transfer.
2. Standard test methods for determining thermal conductivity.
3. Standard methods of expressing the property of thermal conductivity.

The use of refractories, particularly of the fire-clay and silica type, is so intimately connected with the subject of heat insulation that this section will consider not only the properties of recognized high-temperature refractories, but also those materials commonly classed as heat insulators. The development of such specialized materials as silicon carbide, fused alumina and the like, whose ability to transfer heat varies so widely from the commonly used materials of furnace construction, requires at times a specification as to thermal conductivity. Committee C-8 some years ago came to the conclusion that the trade was not ready for specification requirements on thermal conductivity. It is believed that conditions have now changed which make it highly desirable to have such specifications and standard test methods available.

Committee C-8, representing the Society, is cooperating with the Joint Committee on Foundry Refractories in its program of simplification and standardization of foundry refractories. This joint committee was sponsored by the American Ceramic Society and the American Foundrymen's Association and consists of representatives of Federal bureaus and various trade associations and engineering societies interested in the question. Messrs. F. A. Harvey and L. J. Trostel were appointed from Committee C-8 to serve as the Society's representatives in the joint committee.

The committee has re-elected the present officers to serve for the ensuing term of two years.

The recommendations appearing in this report regarding advancing certain tentative specifications, definitions and revisions of methods to standard, have been submitted to letter ballot of the committee, with the following results:

Items	Affirmative	Negative	Not Voting
TENTATIVE STANDARDS ADVANCED TO STANDARD			
1. Specifications for Clay Fire Brick for Malleable Furnaces with Removable Bungs and for Annealing Ovens (C 63 - 27 T)	27	0	5
2. Specifications for Clay Fire Brick for Stationary Boiler Service (C 64 - 27 T)	28	0	4
3. Specifications for Clay Fire Brick for Marine Boiler Service (C 65 - 27 T)	26	1	5
4. Definitions of Terms Relating to Refractories (C 71 - 27 T)	29	0	3
TENTATIVE REVISION OF STANDARDS ADVANCED TO STANDARD			
5. Standard Method of Test for Softening Point of Fire-Clay Brick (C 24 - 20)	27	0	5
6. Standard Definitions for Clay Refractories (C 27 - 20)	29	0	3

This report has been submitted to letter ballot of the committee, which consists of 35 members; 26 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

G. A. BOLE,
Chairman.

L. J. TROSTEL,
Secretary.

EDITORIAL NOTE

The Tentative Specifications for Clay Fire Brick for Malleable Furnaces with Removable Bungs and for Annealing Ovens; for Clay Fire Brick for Stationary Boiler Service and for Clay Fire Brick for Marine Boiler Service were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on September 1, 1928, and appear in the 1928 Supplement to Book of A.S.T.M. Standards.

The Tentative Definitions of Terms Relating to Refractories were approved at the annual meeting as revised by the committee and were subsequently adopted by letter ballot of the Society on September 1, 1928. The definitions in their revised form appear in the 1928 Supplement to Book of A.S.T.M. Standards.

The tentative revisions of the Standard Method of Test for Softening Point of Fire-Clay Brick; and of the Definitions for Clay Refractories were approved at the annual meeting and were subsequently adopted by letter ballot of the Society on September 1, 1928. The method of test and definitions in their revised form appear in the 1928 Supplement to Book of A.S.T.M. Standards.

REPORT OF COMMITTEE C-9
ON
CONCRETE AND CONCRETE AGGREGATES

Committee C-9 is charged by the Society with the responsibility of attending to such of the matters within its purview as relate to concrete and concrete aggregates. The extent to which the committee accepts and meets that responsibility is measured by the number, quality, importance and nature of the standards, reports and papers produced by it. Thus a standing committee's annual report is in the nature of an accounting to the Society for its stewardship.

In rendering this account the items now before this committee are reviewed and the progress made toward disposing of them during the year just passed is noted.

Editorial Sub-Committee IV (A. T. Goldbeck, chairman) makes the following recommendation, which has been approved by Committee C-9:

Standard Method of Making and Storing Specimens of Concrete in the Field (*C 31 - 27*).[1]—

Section 6.—Change the second sentence to read as follows by the addition of the italicized words:

> The cap shall be formed by means of a piece of plate glass *not less than* ¼ in. in thickness or a machined metal plate *not less than* ½ in. in thickness and of a diameter 2 or 3 in. larger than that of the mold.

Sub-Committee V on Definitions (Lewis R. Ferguson, chairman) has done the greater part of its work in conjunction with representatives of other committees of the Society under the auspices of Committee E-8 on Nomenclature and Definitions. The result of this work is being reported by Committee E-8. The terms considered during the past year include sand, aggregate, gravel, crushed gravel, screened crushed gravel, screen (sieve) and concrete. Of these the definitions for sand, screen (sieve) and aggregate are being recommended by Committee E-8 for advancement to standard, the definition for aggregate having been revised somewhat. The definition for concrete is being continued as information. A definition of the term admixture is being developed in Committee C-9.

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 108.

Committee C-9 has approved the advancement to standard of the tentative definitions of sand and aggregate, and screen (sieve) being recommended by Committee E-8 on Nomenclature and Definitions.

Sub-Committee VI on Design of Concrete (R. B. Young, chairman) presents a report, appended hereto, in which are described in detail the steps to be taken in designing a concrete mixture using given aggregates and employing the water-cement ratio method of design. It is the intention to continue work along similar lines and to outline a procedure for the application of the Talbot void-cement ratio method of proportioning concrete. A study has also been started of methods for designing mixtures on the basis of transverse strength.

Sub-Committee VIII on Field Tests of Concrete (H. S. Mattimore, chairman).—To this sub-committee has been assigned the problem of developing a standard method for making transverse strength tests. So much has already been done on this subject by a number of investigators that there should not be great difficulty in formulating a tentative method of test at this time. A sub-committee of Committee D-4 on Road and Paving Materials and of the American Association of State Highway Officials are also at work on this problem and the three committees are working in harmony to avoid duplication of effort.

The sub-committee has been instructed to investigate and recommend revisions of the present Standard Methods of Making and Storing Concrete Specimens in the Field (C 31 – 27) as its first order of business for the coming year.

Sub-Committee IX on Specifications and Methods of Tests of Aggregates (H. F. Clemmer, chairman) has, during the past year, had a section working in conjunction with a sub-committee of Committee D-4 on Road and Paving Materials on a test for abrasion of concrete aggregate. This cooperative work has resulted in a test method which is published with the report of Committee D-4 and which is discussed in detail in a report by the section which appears as Appendix I to this report.

Sub-Committee IX also presents new Tentative Specifications for Concrete Aggregates, appended hereto,[1] as a revision of the present Tentative Specifications for Concrete Aggregate (C 33 – 26 T)[2]

There are also appended hereto as information the following methods of test relating to concrete aggregates:

Proposed Method of Test for Soundness of Coarse Aggregate (Appendix II);

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[1] See p. 822.—ED.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, p. 741 (1926); also 1927 Book of A.S.T.M. Tentative Standards, p. 219.

Proposed Method of Test for Percentage of Shale in Aggregate (Appendix III);

Proposed Method of Test for Quantity of Soft Pebbles in Gravel (Appendix IV);

Proposed Method of Test for Determination of Coal and Lignite in Sand (Appendix V);

Proposed Method of Test for Determination of Total Amount of Moisture in Fine Aggregate by Drying (Appendix VI).

These methods, with the exception of the method for determination of moisture by drying, are now tentative methods of the American Association of State Highway Officials. They will all receive the attention of the sub-committee during the coming year in cooperation with the appropriate committee of the A.A.S.H.O. This procedure is the more readily carried out because of the interlocking membership on the two committees.

One of the members of this sub-committee, Mr. Fred Hubbard, has made a study of the effect of grading on the unit weight of aggregate, a report of which, giving the results of his work, appears as Appendix VII, as the report of the Section on Effect of Gradation on Weights of Materials.

Changes are recommended in the following methods:

Tentative Methods of Test for Field Determination of Approximate Apparent Specific Gravity of Fine Aggregate (C 68 - 27 T);[1]

Tentative Methods of Test for Field Determination of Approximate Percentage of Voids in Fine Aggregate (C 69 - 27 T);[1]

Tentative Methods of Test for Field Determination of Surface Moisture in Fine Aggregate (C 70 - 27 T).[1]

In each of these tentative methods a change of the illustration of the flask to bring it into closer conformity with the flask as manufactured, is recommended. The notes relating to the flask dimensions are modified and all references to the use of charts in connection with the flask are eliminated. These tentative methods in their revised form are appended hereto.[2]

Sub-Committee XI on Apparatus.—This new sub-committee has an opportunity to perform valuable service in its particular field. The Scientific Apparatus Makers of America have offered to cooperate directly with committees of the Society in matters of mutual concern. There are doubtless numerous details of testing machines and devices which are now unsatisfactory because of lack of adequate supervision by the committees which develop the specifications involving their use.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, pp. 794–802 (1927); also 1927 Book of A.S.T.M. Tentative Standards, pp. 223–231.

[2] See pp 827–834.—ED.

Many pieces of equipment for testing are inadequately described in present specifications. It will be the duty of this new sub-committee to improve these conditions.

Sub-Committee XV on Admixtures (George Conahey, chairman) has given most of its attention to the development of a suitable test for workability of concrete. For the use of the sub-committee in the consideration of this subject the following definition of workability has been tentatively agreed upon:

> *Workability.*—Workability of concrete is that property which is indicated by the work required to place the concrete in order to obtain a uniform and homogeneous finished product.

Work is progressing on the development of methods for measuring workability. At the Bureau of Standards, Smith and Conahey have worked with a modification of the penetration method. Purrington, at the New Hampshire State Highway Department, has used a mixer arranged to measure the energy required to mix various concretes and has obtained interesting results which will be presented in a paper before this annual meeting of the Society. The Navy Department, the Portland Cement Association, and others are at work on the problem and the investigations of all will be carefully followed by this sub-committee. In view of the great importance of workability a new sub-committee of Committee C-9 was recently organized to study workability. This sub-committee will not proceed further in the development of tests for workability but will keep in close touch with the progress made by others.

In the study of admixtures the sub-committee has also tentatively agreed upon the following definition for use within the committee:

> *Admixtures.*—An admixture in hydraulic cement is any material other than cement, water or aggregate that may be added to the concrete mixture to effect certain changes in the properties of the concrete.

This definition has been referred to the Sub-Committee on Definitions for consideration. Mr. George Conahey, chairman of this sub-committee, has prepared a brief paper on the effect of admixtures on the water-cement ratio strength relation of concrete which appears as Appendix VIII to this report.

Sub-Committee XVI on Elasticity and Volume Changes of Concrete was reorganized a year ago under the chairmanship of F. E. Richart. Bibliographies have been prepared which are appended hereto with the report of the sub-committee. There is also in preparation a summary of desirable methods of tests for elasticity and volume changes and an outline of investigations on which research is needed.

During the year three members have resigned and ten new members have been added to the roll.

During the year some changes have been made in the subcommittee alignment, the new titles being employed in this report.

At its spring meeting in Washington, April 25, Committee C-9 voted without a dissenting voice to adopt a policy which can hardly fail to have a beneficial effect upon both the quality and the quantity of the committee's work done. That policy, briefly stated, is to limit the membership of Committee C-9 to sixty active workers who by reason of their ability, facilities and interest will each contribute materially to its progress. Sub-committees are to be subject to the same policy and are to be reorganized biennially in the even-numbered years. To become or to remain a member of the main committee or of a sub-committee each must take an active part in the work and contribute helpfully to the ends sought. It is hoped that the carrying out of this new policy will result in an even more creditable accounting of this committee's stewardship in the future than in the past.

The committee has re-elected the present officers to serve for the ensuing term of two years.

The recommendations appearing in this report have been submitted to letter ballot with the following results:

Items	Affirmative	Negative	Not Voting
1. Revision of Tentative Specifications for Concrete Aggregates (C 33 - 26 T)........	56	1	10
2. Revision of Tentative Methods of Test for Field Determination of Approximate Apparent Specific Gravity of Fine Aggregate (C 68 - 27 T)......................	51	0	13
3. Revision of Tentative Methods of Test for Field Determination of Approximate Percentage of Voids in Fine Aggregate (C 69 - 27 T)...........................	55	0	12
4. Revision of Tentative Methods of Test for Field Determination of Surface Moisture in Fine Aggregate (C 70 - 27 T)...	53	0	14

This report has been submitted to letter ballot of the committee, which consists of 67 members; 67 members returned their ballots, of whom 60 have voted affirmatively, none negatively, and 7 have marked their ballots "not voting."

Respectfully submitted on behalf of the committee,

CLOYD M. CHAPMAN,
Chairman.

STANTON WALKER,
Secretary.

EDITORIAL NOTE

The proposed revisions of the Tentative Specifications for Concrete Aggregates; Method of Test for Field Determination of Approximate Apparent Specific Gravity of Fine Aggregate; Test for Field Determination of Approximate Percentage of Voids in Fine Aggregate; and Test for Field Determination of Surface Moisture in Fine Aggregate were accepted. The tentative specifications and methods in their revised form appear on pages 822, 827, 829 and 832, respectively.

REPORT OF SUB-COMMITTEE VI ON DESIGN OF CONCRETE

The previous report of Sub-Committee VI reviewed the theories underlying the design of concrete mixtures and outlined very briefly the five essential steps involved in any application of the most widely used of these, namely, the relationship between water-cement ratio and strength. It is the purpose of this present report to deal with these five steps, first, in a general way and then to illustrate details by application of an example.

Briefly the five steps referred to are as follows:

1. Selection of the cement, aggregate and water.
2. Selection of the strength for which to design.
3. Determination of the proper proportions of fine and coarse aggregate to give the desired workability for the given water-cement ratio.
4. Determination of the water-cement ratio applicable to the materials selected.
5. The conversion of the proportions into field units.

1. *Selection of the Cement, Aggregate and Water:*

Cement.—Provided it conforms to the specifications, the selection of the cement is seldom under the control of the engineer designing the concrete, but when it is, the following considerations should govern:

Although made to one general standard, cements vary considerably in the quantity required to produce a given 28-day compressive strength.

The tendency of present practice is to over-emphasize the importance of high early-strength cements in the manufacture of concrete. The sub-committee wishes to point out that it has not yet been proved that such cements are the best if other factors such as soundness and permanence are given proper weight.

The differences between cements depend, not upon brands, but upon the variation in the materials and production methods of mills, and the engineer, if choosing cements according to their properties, must be certain that shipments are all made from one mill. This is difficult if not impossible to insure in some localities where several mills of one company are producing simultaneously.

Since in field control, it is not often practicable to take advantage of these differences in cements by varying the mixtures, the proportions should be based upon the cement of lowest strength of those that are likely to be used.

Aggregates.—The following are the different steps required in the selection of the aggregate on a job where considerable concrete is to be used. As the size of the job becomes less, certain of these may be omitted.

1. Determination of the available materials. In some cases this will require a field party to search for sources of aggregates and to examine and test-pit those found; in others, little more is required than to examine the materials offered by local producers. Aggregates impossible from the standpoint of availability are eliminated here.

2. Preliminary tests of the different available aggregates for cleanliness, soundness and grading. Aggregates that are not and cannot economically be made satisfactory in these particulars need not be examined further.

3. The remaining aggregates should be made up into mortar or concrete, depending on whether fine or coarse, using a water-cement ratio and a workable consistency that is the same for all specimens. In the case of coarse aggregate, the tests should be made on a slightly oversanded mixture.[1]

These tests will furnish data from which the sources of aggregate to be used may be determined.

2. *Selection of the Strength for Which to Design:*

From necessity, this discussion must deal with the design of concrete for compressive strength, since compressive strength is commonly accepted as the principal measure of the quality of a concrete, but the sub-committee would repeat the statement previously made[2] that it is not "prepared to accept this view and will point out that whereas, broadly speaking the compressive strength of concrete bears a rough relationship to its other mechanical properties, such as resistance to abrasion, transverse and tensile strength, elasticity, permeability and absorption, yet concretes of satisfactory compressive strength do not always possess these properties to the degree desired for a particular purpose. Furthermore, concrete of satisfactory compressive strength may lack durability when exposed to weathering or fire; or it may be permeable and highly absorptive."

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[1] By an over-sanded mixture is meant one containing fine aggregate in excess of the quantity theoretically considered durable. For well-graded coarse aggregate, this condition will usually be met if the sand is at least 40 per cent by weight of the total aggregate.

[2] Report of Sub-Committee IV on Design of Concrete of Committee C-9 on Concrete and Concrete Aggregates, *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 345 (1927).

This sub-committee deals only with the design of concrete mixtures and not with the design of the structure. The selection of the mechanical properties (strength, resistance to weathering, impermeability, etc.) desired for the structure is part of the design of the structure and is entirely within the province of the designing engineer.[1]

Having the strength of concrete at a given age specified for the structure, the strength for which the mixture should be designed can be selected. The sub-committee believes the concrete should be designed so that the average 28-day strength obtained from the field specimens will be equal to the strength specified. It well appreciates that the variations from the average strength will be dependent partly upon the uniformity of the materials used, partly on methods and skill used in making, curing and testing the specimens, but more especially on the control of the constituent materials, cement, water and aggregates, and that when the degree of control is liable to be unsatisfactory, the designing engineer should take cognizance of this in setting the average strength for the concrete.

In recommending this system the sub-committee does so believing that the variations in the field test specimens, under our present testing methods are greater than the variations in the concrete represented by them. Under good control the average variation in strength of all specimens will occasionally reach 20 per cent but ordinarily, where curing conditions and laboratory facilities are good,[2] will be nearer 15 per cent.[3]

3. *Determination of the Proper Proportions of Fine and Coarse Aggregate to Give the Desired Workability for the Given Water-Cement Ratio:*

The sub-committee suggests as a method for the determination of the proper proportions of the fine and coarse aggregate, the following procedure.

Consideration of workable mixes which have been much used indicate that the proper ratio of fine to coarse aggregate can be estimated with reasonable accuracy from the grading of the fine aggregate and from the range in sizes and grading of the coarse.

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[1] Helpful suggestions in the matter will be found in the following: Report of the Joint Committee of Standard Specifications for Concrete and Reinforced Concrete, *Proceedings*, Am. Soc. Testing Mats., Vol. 24, Part I, p. 303 (1924); Appendix II, Report of Committee C-9 of Concrete and Concrete Aggregates, *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 383 (1927); "Design and Control of Concrete Mixtures," 2nd Edition, Portland Cement Association.

[2] It is very important that the curing temperature of field specimens be maintained at from 65 to 70° F. and that they be kept moist.

[3] A discussion of variations in field tests may be found in "The Field Testing of Concrete" by R. B. Young, *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part II, p. 390 (1927).

The usual ratio with a well-graded[1] sand and coarse aggregate graded to a maximum size of 2 in. would be approximately 2:3 by weight.

More especially the following factors will effect an increase in the amount of sand:

(*a*) The use of coarse aggregate of a limited range of sizes (one size).

(*b*) A decrease in the maximum size of the coarse aggregate.

(*c*) A sand containing a large proportion of coarse particles.

Conversely a decrease in the ratio is effected by an increase in the maximum size of the coarse aggregate and also by an increase in the proportion of fine particles in the sand.

The ratio, as assumed from a consideration of the above, affords a starting point for trial determinations from which the final proportion of fine to coarse aggregate is found.

4. *Determination of the Water-Cement Ratio Applicable to the Material Selected:*

It is the opinion of the sub-committee that ordinarily the water-cement ratio - strength relationship should be determined experimentally for the materials selected. The relationship varies with different cements and different aggregates as used and, accordingly, accuracy and economy demand that it be known exactly for any given case.

The sub-committee recommends for this purpose that at least five different mixtures of the cement and air dried aggregates for the job under consideration be made up using over-sanded mixtures. The tests should be carried out in accordance with the standards[2] of the Society using from 3 to 5 specimens for each different mixture made with the consistency proposed for the job.

The proportions of the different mixtures should be selected to cover more than the range of strength for which concretes are likely to be designed. A margin of 500 lb. per sq. in. below and above is generally sufficient. Usually a range from 1000 to 4000 lb. per sq. in. for an age of 28 days is satisfactory and ordinarily this may be obtained by selecting proportions having water-cement ratios varying between 1.30 and 0.65. If the required compressive strength of the concrete is likely to equal or exceed 4000 lb. per sq. in. at 28 days, the tests should include water-cement ratios as low as 0.55.

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[1] A fine aggregate in accord with the requirements of the A.S.T.M. Tentative Specifications for Concrete Aggregates (C 33 – 27 T) or the Standard Specifications for Concrete and Reinforced Concrete of the Joint Committee would be considered to be well graded.

[2] Standard Methods of Making Compression Tests of Concrete (Serial Designation: C 39 – 27), 1927 Book of A.S.T.M. Standards, Part II, p. 112.

The following information should be obtained for each mixture.

(*a*) Amount of cement per cubic foot of concrete.

(*b*) Weight of concrete per cubic foot.

(*c*) Compressive strength.

(*d*) Water-cement ratio.

In determining the water-cement ratio proper allowance must be made for the water absorbed by the aggregates.

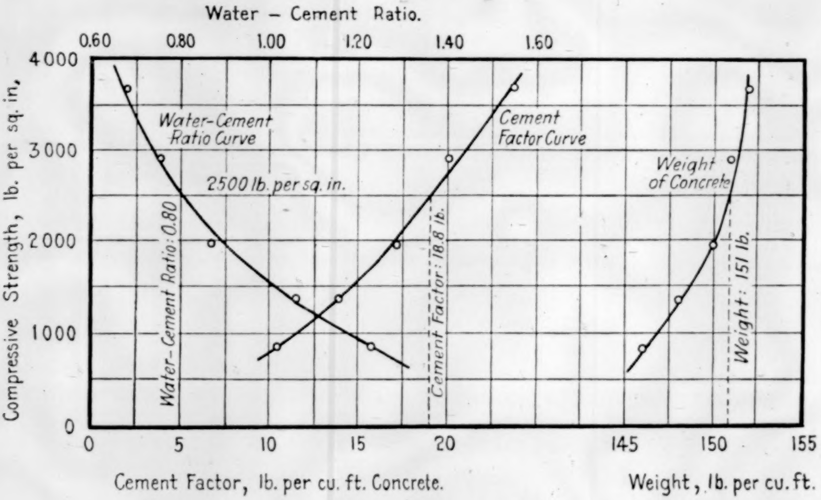

FIG. 1.—Data from Concrete Proportioning Tests.

From these data, curves should be prepared showing the relationship of compressive strength to water-cement ratio, to quantity of cement and to the weight per cubic foot of concrete.

5. The final step in the design of a concrete mixture is the conversion of the data obtained in the foregoing operations into a form in which they may be used in the field. This probably can best be explained by working out an actual example.

Proportions are usually expressed as a ratio, for example 1:2:4, meaning a mixture in which 1 cu. ft. of cement is used to each 2 cu. ft. of fine aggregate and 4 cu. ft. of coarse aggregate. Here one sack of cement is ordinarily assumed to contain a cubic foot and the aggregates are measured dry and rodded in the manner prescribed by the Society.[1]

In the field, it is necessary to determine the quantities required for a certain size batch of concrete and these quantities must be in the units used on the job, that is, in pounds, if measurements are by weight or sacks and in cubic feet, if measurements are by volume.

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[1] Standard Method of Test for Unit Weights of Aggregate for Concrete (Serial Designation: C 29 – 27), 1927 Book of A.S.T.M. Standards, Part II, p. 120.

Examples will be worked out therefore giving proportions in the usual ratio of volumes and in batch quantities by weight and by volume.

Example:

For our example let us assume that a concrete is to be designed for a compressive strength of 2500 lb. per sq. in. at 28 days and that tests made on the materials to be used, as outlined under item 4, have given the following basic data:

Fine aggregate.—Fineness modulus 2.7, weight per cubic foot (dry, rodded) 116 lb., absorption 1.5 per cent by weight.

Coarse aggregate.—Fineness modulus 7.0, weight per cubic foot (dry, rodded) 111 lb., absorption 0.4 per cent by weight.

Ratio of fine to coarse aggregate.—40:60 by weight.

Data Obtained from Proportioning Test.—

Cement, per cent by weight of Aggregate	Water, per cent of Aggregate	Water-Cement Ratio[a]		Weight of Concrete, lb. per cu. ft.	Compressive Strength, lb. per sq. in.	Cement Factor, lb. per cu. ft. of Concrete
		By weight	By volume			
7.5	7.3	0.86	1.29	146	820	10.5
10.0	7.9	0.71	1.06	148	1350	13.9
12.5	8.1	0.58	0.87	150	1960	17.2
15.0	8.4	0.50	0.75	151	2900	20.1
18.0	9.0	0.45	0.68	152	3700	23.7

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[a] Corrected for absorption.

Plotting these data as in Fig. 1 affords a means of obtaining the cement content, the water content and the approximate weight of 1 cu. ft. of any class of concrete falling within the range of the tests.

Let us first determine the quantities required for 1 cu. ft. of 2500-lb. concrete. According to the test data, 1 cu. ft. of this class of concrete weighs 151 lb. and contains 18.8 lb. or approximately 19 lb. of cement. With a water-cement ratio of 0.80, the water content of such a concrete would be 10 lb. The weight of the aggregate in 1 cu. ft. would therefore be $151 - (19 + 10) = 122$ lb. This is made up of 40 per cent or 49 lb. of fine and 60 per cent or 73 lb. of coarse aggregate. Taking cement as unity, the proportions by weight are, therefore, 1.00:2.58:3.85. Transposing the weights into volumes, by dividing them by the weight per cu. ft. of the respective materials, the quantities become:

Cement.................................... $\frac{19}{94} = 0.202$ cu. ft.

Fine Aggregate............................ $\frac{49}{116} = 0.423$ cu. ft.

Coarse Aggregate.......................... $\frac{73}{111} = 0.658$ cu. ft.

or taking cement as unity, the proportions by dry rodded volumes become:

$$1.00:2.10:3.26 \text{ or approximately } 1:2\tfrac{1}{10}:3\tfrac{1}{4}.$$

The amount of water required to give a water-cement ratio of 80 is 0.80 cu. ft. or with water weighing 62.5 lb. per cu. ft. and 8.33 lb. per gallon this becomes $\frac{0.80 \times 62.5}{8.33} = 6.00$ gal. of water per sack of cement.

Proportions such as these are not however in field units. On a job it is necessary to know the quantities of cement, aggregate and water for a given size batch. For purposes of illustration let us calculate the quantities required to give one cubic yard of concrete when the fine and coarse aggregates as received, contain 3.5 and 1.00 per cent moisture, respectively.

Since in this example a cubic foot of the concrete weighs 151 lb. and the size of the batch is 1 cu. yd. or 27 cu. ft. the weight of the batch would be $151 \times 27 = 4077$ lb.

Each cubic foot of concrete contains 19 lb. of cement or a batch contains $27 \times 19 = 513$ lb.

With a water-cement ratio of 0.80 the amount of water required for 513 lb. of cement would be $\frac{0.80 \times 513 \times 62.5}{94} = 273$ lb.

(94 lb. of cement and 62.5 lb. of water are taken as equal to 1 cu. ft. This calculation would be much simpler if the water-cement ratio were expressed as a ratio of weights and not of volumes.)

The 4077 lb. of concrete is therefore made up of:

Cement		513 lb.
Water		273 lb.
Aggregate	$4077 - (513 + 273) =$	3291 lb.

Of this, the aggregate is divided as follows:

40 per cent is sand	$0.4 \times 3291 =$	1316 lb.
60 per cent is gravel	$0.6 \times 3291 =$	1975 lb.

The moisture contained by the sand and gravel as delivered on the job was found by test to be 3.5 and 1.0, respectively, but the absorption of these aggregates, as previously determined, is known to be 1.5 and 0.4 per cent, respectively Therefore, the free moisture held by the aggregates is 2.0 and 0.6 per cent and the weight of water that must be determined and corrected for is:

Weight of water in sand	$\frac{1316 \times 2.0}{100} =$	26 lb.
Weight of water in gravel	$\frac{1975 \times 0.6}{100} =$	12 lb.

The field weights are therefore:

Sand	$1316 + 26 =$	1342 lb.
Gravel	$1975 + 12 =$	1987 lb.
Water	$273 - (26 + 12) =$	235 lb.

Hence, the field proportions, if by weight, are:

Cement	513 lb. or $\frac{513}{94}$	= 5.46 bags
Sand (moist)		= 1342 lb.
Gravel (moist)		= 1987 lb.
Water (net)	235 lb. or $\frac{235}{8.33}$	= 28.2 gal.

Generally, cement is measured in bags and when this is done it is probable that the above batch would be adjusted to use 5½ bags of cement[1]:

Cement	517 lb. or	5½ bags
Sand (moist)		1355 lb.
Gravel (moist)		2000 lb.
Water	237 lb. or	28.5 gal.

Where volume measurements are used, the above weights must be converted into volume units and to do this it is necessary to know the weight per cubic foot of the aggregates as measured at the mixer. Assume that for this case they are 91 lb. for the sand and 104 lb. for the gravel. The field proportions would become, therefore:

Cement	5½ bags
Sand (moist) $\frac{1355}{91}$	14.9 cu. ft.
Gravel (moist) $\frac{2000}{105}$	19.0 cu. ft.
Water	28.5 gal.

Respectfully submitted on behalf of the sub-committee,

R. B. YOUNG,
Chairman.

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[1] This is an unnecessary refinement in the example used, since the quantity of cement required is so nearly equal to 5½ bags, but the procedure is given because, in many cases, it is necessary to make this adjustment.

APPENDIX I

REPORT OF SECTION ON ABRASION TESTS OF CONCRETE AGGREGATES

Abrasion tests of aggregates for concrete have been the subject of considerable study by engineers in an effort to establish a relation between this factor and the concrete-making properties of the aggregate. The standard Deval abrasion test was developed by the School of Roads and Bridges in France during the latter part of the nineteenth century in connection with early studies of crushed stone for macadam road construction.[1] The practice of using this test soon found its way to the United States and it became, with no essential changes, one of the standard test methods of the American Society for Testing Materials in 1908.[2] The standard test and various modifications of it are in general use as one of the measures of quality of concrete aggregates for that purpose.

In spite of the researches which have been carried out on this problem, little definite information has been developed which permits of the establishment of specification limits or which provides a common basis for the comparison of aggregates of different types. It is the purpose of this report to present a brief statement on the status of information on abrasion tests of aggregate. No attempt will be made to give a summary of the many researches which have been carried out on this subject, but reference will be made to the more important sources of information.

DEVAL ABRASION TESTS FOR CRUSHED STONE

The standard Deval abrasion test is the method generally required by specifications for abrasion of crushed stone for concrete aggregates. This test consists of running a 5000-g. sample of 50 pieces in the Deval machine for 10,000 revolutions and measuring the loss through a No. 12 sieve after the test. As originally developed, it was for the purpose of selecting stone of suitable resistance to impact and abrasion for use in water-bound macadam road construction. Although it was found to be quite satisfactory for that purpose, improvements in the test were considered as early as 1902. The effect of number of pieces of rock in the test sample, number of revolutions of the cylinder required for an indicative test and the effect of eliminating the dust during the test were some of the objects of these early studies.[1]

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[1] "Original Work of Deval in Developing Abrasion Test for Crushed Rock for Use in Macadam Road Construction," *Annales des Ponts et Chaussées*, 1879; *Bulletin Ministere des Travaux Publique*, 1881.

[2] Standard Method of Test for Abrasion of Rock (D 2 - 26), 1927 Book of A.S.T.M. Standards, Part II, p. 463.

With the increased use of concrete, the standard Deval abrasion test was continued as a method for comparing the quality of stone from various sources for use as coarse aggregate. It was recognized that the application of this test to concrete aggregates was not as logical as its use in connection with macadam stone, but no remedial change has as yet been adopted nor has any suitable substitute been developed.

Test data are available which show that the resistance to abrasion of stone as measured by the standard Deval test is not an indication of the quality of concrete in which it isused, in so far as compressive strength is concerned.[2, 3] It has been shown that the surface wear of concrete may be influenced by the resistance to abrasion of the aggregate,[4] and there are some indications that the transverse and tensile strength of concrete may be influenced by this factor.

Many modifications of the test method have been suggested, some of which seem to have shown distinct advantages over the present standard method, but none of them has come into general use. The principal objection to the standard abrasion test for stone is that the sample for the test cannot be obtained from the supply furnished for concrete aggregates, if the standard method is followed in all its details. The method requires that the rock to be tested be broken in pieces as nearly uniform in size as possible and that as nearly 50 pieces as possible shall constitute a test sample. Although not specifically indicated by the wording of the present specifications, it is generally understood and was required by earlier specifications that the 50 pieces are to be freshly broken by hand and approximately cubical in shape. Particles of sufficient size to permit of preparation of the sample in this manner would rarely, if ever, be in a supply of concrete aggregates.[5]

One test which was proposed for graded samples of either crushed stone or gravel made use of a horizontal cylinder built up from staves past which the dust of abrasion could escape. The test sample was composed of 1250 g. of $\frac{1}{2}$ in. to 1 in. size, 1250 g. of 1 in. to 2 in. size, and an abrasive charge of six cast-iron spheres $1\frac{7}{8}$ in. in diameter. Two thousand revolutions were recommended for a test of stone and four thousand for a test of gravel.[1] In a discussion of this method the well known "slotted cylinder" test was described by Mattimore.[1]

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[1] "Improvements in Tests of Macadam Materials," *Engineering Record*, Vol. 45, p. 365, April, 1902.

[2] F. E. Giesecke, "Aggregate Strength No Measure of Concrete Strength," *Engineering News-Record*, Vol. 88, June 29, 1922, p. 1090.

[3] Stanton Walker, "Effect of Type of Coarse Aggregate on Quality of Concrete," *Concrete*, Vol. 27, August, 1925, p. 40.

[4] F. H. Jackson and J. T. Pauls, "Accelerated Wear Tests of Concrete Pavements," *Proceedings*, Am. Soc. Testing Mats., Vol. 24, Part II, p. 864 (1924); *Public Roads*, May, 1924. Report of Committee E-5 on Aggregates, *Proceedings*, Am. Concrete Inst., 1927.

[5] F. H. Jackson, "The Standard Deval Abrasion Test for Rock," *Proceedings*, Am. Soc. Testing Mats., Vol. XX, Part II, p. 278 (1920); *Public Roads*, July, 1920.

A modification of the test which was suggested by the U. S. Bureau of Public Roads,[2] requires the independent testing in abrasion of several stone samples of different size particles, each composed of 50 pieces uniform in size and of smaller than standard dimensions, and plotting a curve of size against percentage of wear from which a result approximating the standard test result may be determined. The laborious method of obtaining the result and the room for reasonable doubt as to even approximate accuracy for the whole range of possible materials form the basis for serious objection to this procedure as a standard.[3]

The preceding brief discussion should show that definite and correlated information with reference to the use of the Deval abrasion test for stone as a criterion of its concrete-making properties is not available. This committee feels that the present standard Deval abrasion test should be modified to make it more suitable for use in tests of concrete aggregate, but more data are needed before any definite recommendations can be made.

DEVAL ABRASION TESTS FOR GRAVEL

Test Methods:

It became evident at once that the standard test method could not be applied to gravel because of the requirement for shape of particle and grading of sample. Consequently a number of different investigations were carried out looking toward the development of a modification of the test suitable for gravel. In these investigations the attempt was made not only to develop a test method, but also to establish a relationship between some measure of resistance to abrasion of gravel and that of crushed stone as measured by the standard test. These investigations have covered studies of effect of size and grading of sample, amount of abrasive charge, revolutions of cylinder, effect of removing dust through slots in the cylinder, tests of type of abrasion machine other than the Deval machine, and other variables.[1]

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[1] H. H. Scofield, "An Abrasion Test for Stone, Gravel, and Similar Aggregates" (also discussion by H. S. Mattimore), *Proceedings*, Am. Soc. Testing Mats., Vol. XVIII, Part II, p. 416 (1918); *Good Roads*, Vol. 16, p. 108, September 21, 1918; Abstract, *Engineering News-Record*, Vol. 81, July 4, 1918, p. 53.

"Use of Slotted Cylinder for Deval Abrasion Test of Rocks," Report by N. Y. Commissioner of Highways, 1917.

[2] "Abrasion Test for Crushed Rock," *Public Roads*, November, 1924; *Engineering and Contracting*, Vol. 63, January 7, 1925, p. 23.

[3] T. B. Shertzer, "Deval Test for Crushed Stone," *Rock Products*, Vol. 28, April 4, 1925, p. 41.

As a result of the early investigations, the American Association of State Highway Officials adopted tentatively, in 1917, a method of test first proposed by A. S. Rea of the Ohio State Highway Department in 1914.[2] This test consisted of running a sample of 5000 g., made up of 2500 g. of $\frac{1}{2}$ in. to 1-in. material and 2500 g. of 1 in. to 2-in. material, in a standard Deval abrasion testing machine for 10,000 revolutions with six $1\frac{7}{8}$-in. cast-iron balls added as an abrasive charge.[3]

In 1920 the specifications for the grading of the sample were revised to require 1250 g. of each of the following four sizes: $\frac{1}{2}$ in. to $\frac{3}{4}$ in., $\frac{3}{4}$ in. to 1 in., 1 in. to $1\frac{1}{2}$ in., and $1\frac{1}{2}$ in. to 2 in. This latter method has remained as the tentative standard of the American Association of State Highway Officials until this year and has been incorporated in most specifications for gravel of the various state highway departments.

While this modified method was found to be very useful in studies of gravel, several objections to it developed with experience in using it. No conclusive information has been developed which shows any relationship between the results of this test and of the concrete making properties of the gravel from which generally applicable specification limits may be derived, and, as a result, the limitations on the percentage of wear vary over a wide range and reflect the judgment of the engineer based on studies of materials in different localities. Attempts to correlate the results of abrasion tests of gravel by the modified method with those of crushed stone made by the standard method have not been successful. Due to the grading of the sample required, the test cannot be made on all gravels since the necessary sizes may not be available. In the case of gravel containing a considerable proportion of sizes finer than $\frac{1}{2}$ in. the test sample is not representative of the grading as a whole. For gravel containing a considerable quantity of crushed particles the percentage of wear is considerably greater than on gravel of the same characteristics, but containing no crushed particles.

Recognizing these objections, particularly those relating to the impracticability of making the test on certain gravels on account of their grading, the American Association of State Highway Officials has revised the test method to permit the use of samples of four different gradings and to take into account the effect of crushed particles.

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[1] See 1928 Report of Committee E-5 on Aggregates of the American Concrete Institute for a more complete discussion of investigation and references to the literature, *Proceedings*, Am. Concrete Inst., Vol. XXIV, p. 777 (1928).

[2] A. S. Rea, "Standard Abrasion Test for Gravel Employed by the Ohio State Highway Department," *Good Roads*, June 6, 1914.

[3] "Standard Form for Specifications, Tests, Reports and Methods of Sampling for Road Materials," U. S. Department of Agriculture *Bulletin No. 555*.

Prior to presenting the proposed method to the Committee on Materials of the American Association of State Highway Officials it was discussed and revised at an informal conference at which representatives of that committee, Committee E-5 on Aggregates of the American Concrete Institute, and the Society's Committees C-9 on Concrete and Concrete Aggregates and D-4 on Road and Paving Materials were present. It was agreed that the proposed test method should be presented for the consideration of each of the above organizations. It has been tentatively adopted by the American Association of State Highway Officials and by the American Concrete Institute and is being considered by Committee C-9. It has been recommended for publication by the Society as tentative by Committee D-4 and it is included with the report of that committee.

The method, as originally outlined, is based on the use of screens with circular openings. Committee C-9 has adopted sieves with square openings as a standard for use in its specifications; on the other hand, Committee D-4 has adhered to the use of round openings for testing purposes. Sufficient information is not available to determine which square sieves give a separation equivalent to the various round screens. It is hoped that other activities of the Society, which are now under way, will result in the adoption of a definite practice with respect to round and square openings for testing sieves. In view of this disagreement in practice the committee has designated "round or square" openings with a reference to the following note:

> The question of whether or not round or square openings shall be used for testing aggregates is now being studied by the Section on Coarse Screens of the Technical Committee on Size and Shape of Committee E-1 on Method of Testing.

Until a decision is reached on this question it is impossible to outline the test method so that it may readily be incorporated in the specifications of the various committees interested.

Specification Limits:

Thus far the committee has considered only the development of a method of test without reference to specification limits. It is recognized that, in order for the method to become useful, limiting percentages of wear should be determined. There is not, however, sufficient information available to permit fixing such limits at this time, and there would seem to be considerable doubt if it is practicable to arrive at test limits which will be generally applicable.

In the seven or eight years of experience which have been had by engineers and research organizations with the modified method adopted by the American Association of State Highway Officials no conclusive information has been developed which shows a definite relationship between the resistance to abrasion of gravel and its concrete making properties. In fact, most of the test data available seem to indicate that the compressive strength and resistance to abrasion of concrete are not affected, within wide limits, by the resistance to abrasion of the aggregate particles. There are some indications that the transverse and tensile strengths of the concrete may be influenced by the resistance to abrasion of the coarse aggregate.

The test may prove useful, however, in furnishing a means for drawing a line of demarcation between distinctly unsuitable and suitable gravels for different purposes in various localities. The specification limits will depend on local conditions and should be determined from records of service. The test should also serve to detect the presence of soft and friable particles.

Preparatory to setting test limits it will also be necessary to establish the relationship between the percentages of wear obtained for the different gradings recommended. Work is now under way on this question and the available data have been collected by Wallace F. Purrington, chairman of Section III on Abrasion of the Non-Bituminous Sub-Committee of Committee D-4. These data are published as an appendix to the report of Committee D-4.

The results of these tests are somewhat discouraging to the hope of establishing a definite relationship between the resistance to abrasion of the differently graded samples. It seems apparent from these tests that the relationship among the different gradings depends upon the physical characteristics of the gravel. Further study is required before it can be stated if this variation is a function of any known property of the gravel. It probably depends on the size and amount of particles of the various constituents, and will vary for each gravel.

Other Investigations to be Reported:

At the Structural Materials Research Laboratory an investigation of abrasion tests of different aggregates was carried out through the cooperation of the Portland Cement Association and the Lewis Institute. These tests included studies of effects of number of revolutions of cylinders, weight of sample, number of shot in abrasive charge, grading of sample and shape of particle. The results of these tests are included in a paper by Stanton Walker presented before the Society this year.[1]

Tests on a large number of different gravels using different gradings and methods of tests and on a number of crushed stones which had been rounded in the Deval machine have been carried out by the Illinois Division of Highways which furnish valuable information on the relation between the standard test for crushed stone and the modified test for gravel and also upon the effect of physical characteristics of gravel on the resistance to abrasion, offered by different gradings of sample.

Reference should be made to data included in a thesis submitted by Bernard T. Schad to the University of Michigan for the degree of Master of Science. Tests were made in a study of the effects of grading of sample, amount of abrasive charge, and slots in cylinder. A number of different gravels were also tested using one method of test. This thesis is published in the Proceedings of the Thirteenth Annual Conference on Highway Engineering held at the University of Michigan in 1927.

DEVAL ABRASION TESTS OF SLAG

A symposium on abrasion tests of slag has been prepared by H. J. Love of the National Slag Association and has been made available to the committee. This symposium contains such a mass of information that the committee has not had an opportunity to make a suitable summary of it for inclusion in this report.

Respectfully submitted on behalf of the section,

STANTON WALKER,
Chairman.

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[1] Stanton Walker, "Studies of Methods of Making Deval Abrasion Tests of Aggregates," *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part II, p. 745 (1928).

APPENDIX II

PROPOSED METHOD OF TEST
FOR
SOUNDNESS OF COARSE AGGREGATE
(Sodium Sulfate Soundness Test)

1. *Procedure.*—Immerse 10 small pieces (total about 1000 g.) of the rock in a saturated solution of sodium sulfate at 70° F. for 20 hours, after which, place them for 4 hours in a drying oven maintained at a temperature of 100° C. Repeat this treatment .... times. The operation of immersing, heating, reimmersing, reheating, etc., shall be continuous, and the material shall be allowed to cool to approximately the temperature of the solution before reimmersing. Note the condition of the rock as to soundness at the end of the test.

2. *Rejection.*—Samples which exhibit marked disintegration shall be considered to have failed in this test. Failure in the test, when accompanied by evidence of weathering of the exposed surface, may be considered sufficient ground for rejection.

NOTE.—A correct interpretation of the results of the sodium sulfate soundness test will be greatly assisted by a visual examination of the ledge from which the sample was obtained.

APPENDIX III

PROPOSED METHOD OF TEST
FOR
PERCENTAGE OF SHALE IN AGGREGATE

1. For the separation of shale and other pieces having a low specific gravity from concrete aggregate, a solution of zinc chloride ($ZnCl_2$) or some other satisfactory liquid having a specific gravity of approximately 1.95 should be used. A sample of the pebbles shall be dried to constant weight at not over 110° C. and then placed in a container partially filled with the solution. The mixture shall be agitated for five minutes, the lighter materials skimmed off, and the solution passed through a sieve which will retain the pebbles. This operation shall be repeated until the entire sample has been separated. The aggregate retained on the sieve shall be dried to constant weight at not over 110° C. and the volume determined.

NOTE.—Attention is called to the fact that this method of test is not applicable when the specific gravity of the shale exceeds the specific gravity of the zinc-chloride solution. In cases where a solution of very high density is required, a mixture of bromoform and benzol may be employed in place of the zinc-chloride solution.

2. The percentage, by volume, of shale or other soft material shall be calculated on the original sample.

APPENDIX IV

PROPOSED METHOD OF TEST
FOR
QUANTITY OF SOFT PEBBLES IN GRAVEL

1. *Scope.*—This method consists in determining the resistance of the pebbles in gravel to static pressure.

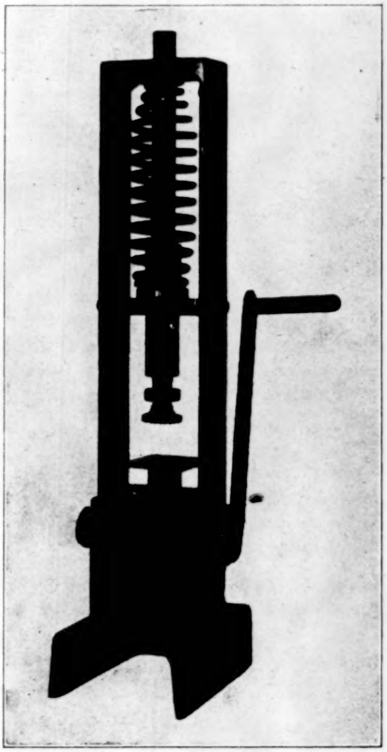

FIG. 1.—Douglass Machine for Classifying Soft Stone.

2. (*a*) ***Procedure.***—A 1000-g. sample of the gravel shall be separated into the following three sizes and each particle of the several sizes shall be subjected to a uniform pressure without impact, as follows:

SIZE	UNIFORM PRESSURE
0.185 in. to 0.375 in., exclusive	35 lb.
0.375 in. to 0.750 in., exclusive	60 lb.
0.750 in. and larger	75 lb.

(*b*) Disintegrated rocks or other rocks which will obviously break up into fine material during the screening or mixing operation shall not be considered in this test.

NOTE.—A satisfactory apparatus for classifying soft stone by this method is the Douglass[1] stone machine shown in Fig. 1. The machine consists of a jack acting through the specimen to compress a calibrated spring. The jack, which is of the rack and pinion type, is located in the base of the machine and is actuated by means of a hand lever attached to the shaft of the pinion. To the base are attached two vertical standards which are attached to each other by two cross members, one at the top and one near the center. The coil compression spring is located between these two cross members. The top of the spring bears against the top cross member and the bottom against a collar on the movable plunger which passes through both cross members and the spring. To the lower end of the plunger is screwed a mechanic's jack which allows adjustment for the various sizes of stones and also carries a ball and socket head. The top end of the movable plunger is graduated to read the desired pressures as it passes through the top cross member.

3. *Report.*—Pebbles crushing under these loads shall be classed as soft pebbles and shall be reported as percentage, by weight, of the original sample.

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[1] This apparatus was devised by the late W. H. Douglass of the Iowa Highway Commission.

APPENDIX V

PROPOSED METHOD OF TEST
FOR
DETERMINATION OF COAL AND LIGNITE IN SAND

1. *Scope.*—This method is intended for the approximate determination of coal and lignite in the routine laboratory examination of sands. This method separates, along with the coal and lignite, other particles of low specific gravity, such as small pieces of wood, vegetable matter, etc.

2. *Apparatus.*—The apparatus shall consist of the following:

(*a*) *Balance.*—The balance shall have a capacity of at least 200 g. and shall be sensitive to 0.01 g. A less sensitive balance may be used in weighing the wet sample.

(*b*) *Aluminum Pan.*—An aluminum pan of about 500-cc. capacity.

(*c*) *Beakers.*—Two 400-cc. tall-form, lipped beakers.

(*d*) *Wire Gauze or Sieve.*—One copper or brass-wire gauze or a small 3-in. sieve having about 60 openings per inch. A piece of wire gauze would probably be better adaptable than a sieve.

3. *Procedure.*—Weigh a quantity in excess of 200 g. of sand (sampled wet from the bag) and dry on a hot plate. Weigh accurately a 200-g. sample of the dry sand to the nearest 0.01 g. Pour this sample slowly into about 250 cc. of carbon tetrachloride (sp. gr. about 1.58) contained in one of the 400-cc. beakers. Place the wire gauze or 3-in. sieve over the other 400-cc. beaker and pour the carbon tetrachloride through the gauze or sieve, taking care that the coal and floating particles, but none of the sand, are retained on the gauze or sieve. If the coal content seems high after this treatment the sand may once more be covered with the liquid, agitating the mixture with a spoon or wide spatula and allowing the sand to settle. The gauze or sieve containing the coal and the other particles will dry very quickly, but may be placed in an oven at 105° C. for a few minutes if desired. The particles of coal shall then be brushed from the gauze or sieve onto the balance pan and the weight accurately determined to the nearest 0.01 g.

4. *Calculation.*—The percentage of coal shall be calculated from the following formula:

$$\text{Percentage of coal} = \frac{\text{Weight of Coal}}{\text{Weight of dry sample (200 g.)}} \times 100$$

APPENDIX VI

PROPOSED METHOD OF TEST
FOR
DETERMINATION OF TOTAL AMOUNT OF MOISTURE IN FINE AGGREGATE BY DRYING

1. *Scope.*—This method of test is intended for use in determining the total amount of moisture in sand and other fine aggregates.

2. *Procedure.*—A quantity of the fine aggregate weighing about 1 kg. shall be selected from which a 500-g. sample shall be accurately weighed immediately, permitting as little moisture as possible to evaporate from the sample. The 500-g. sample shall be dried to constant weight at a temperature not exceeding 110° C. (230° F.) and the weight after drying determined.

3. *Calculation.*—The results shall be calculated from the formula:

$$\text{Percentage of moisture (dry basis)} = \frac{\text{Original Weight} - \text{Weight after Drying}}{\text{Weight After Drying}} \times 100$$

APPENDIX VII

REPORT OF SECTION ON EFFECT OF GRADATION ON WEIGHTS OF MATERIALS

It is generally understood that radical changes in gradation of coarse aggregate will affect to a certain extent the unit weight of the aggregates. The Section on Effect of Gradation on Weights of Materials of Sub-Committee IX on Aggregates has developed data, as well as compiled data already available, showing the effect on weight of widely different gradings as well as the effect of slight differences in gradation which would fall within the usual specification limits.

In carrying on this work, the standard methods of the Society have been followed in so far as possible. The data presented herewith seem to prove conclusively that the gradation of coarse aggregate does affect the unit weight considerably, and that any specifications developed having a unit weight requirement should show the grading of the material to which the weight requirement applies. The data which have been assembled are given below.

Reported by E. F. Kelley on Stone and Gravel

Results of weight determination were reported by E. F. Kelley, Chief, Division of Tests, U. S. Bureau of Public Roads, on thirteen gradings of stone (traprock) having a specific gravity of 2.95, and gravel having a specific gravity of 2.65. The weight determinations were made in accordance with the Society's Standard Method of Test for Unit Weight of Aggregate for Concrete (C 29 – 27):[1]

Weight Per Cubic Foot and Gradation of Aggregate

Grading	Percentage Passing Each Screen (Round-Hole Screens)									Weight per Cubic Foot, lb.	
	3-in.	$2\frac{1}{2}$-in.	2-in.	$1\frac{1}{2}$-in.	1-in.	$\frac{3}{4}$-in.	$\frac{1}{2}$-in.	$\frac{1}{4}$-in.	$\frac{1}{8}$-in.	Stone	Gravel
No. 3	100	80	65	45	30	..	15	5	0	110	108
No. 4	100	75	50	25	0	..	..	..	..	97	97
No. 5	..	100	85	70	50	40	25	5	0	106	107
No. 6	..	100	75	55	35	25	15	5	0	103	108
No. 7	..	100	65	35	0	..	..	..	..	94	96
No. 8	..	..	100	85	60	40	30	10	0	102	106
No. 9	..	..	100	70	40	30	20	5	0	103	105
No. 10	..	..	100	60	20	0	..	..	..	97	97
No. 11	..	..	100	40	30	25	20	5	0	104	107
No. 12	..	..	..	100	80	60	40	10	0	97	105
No. 13	..	..	..	100	60	40	15	5	0	98	104
No. 14	..	..	..	100	40	10	0	..	..	94	98
No. 16	..	..	..	..	100	50	0	..	..	90	97

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 120.

REPORTED BY MALCOLM H. ULMAN ON STONE AND GRAVEL

Results of weight determinations of three gradings of stone and gravel were reported by Malcolm H. Ulman, Assistant Engineer of Materials, Pennsylvania State Highway Department, Harrisburg, Pa. These determinations were made by shaking the material to refusal in a cubic foot box. The material was placed in the box in three separate layers, each layer being compacted as much as possible by shaking:

STONE

Grading:	GRADING No. 1	GRADING No. 2	GRADING No. 3
Passing 2½-in. round-hole screen, per cent	100	100	100
Passing 1¼-in. round-hole screen, per cent	65	35	50
Passing ⅝-in. round-hole screen, per cent.	15	0	7.5
Passing ⅜-in. round-hole screen, per cent.	8	0	4
Specific Gravity......................	2.62	2.62	2.62
Compact Weight, lb. per cu. ft............	105.75	101.25	103.75
Percentage of Voids.....................	36	39	37.5

GRAVEL

Grading:	GRADING No. 4	GRADING No. 5	GRADING No. 6
Passing 2¾-in. round-hole screen, per cent	100	100	100
Passing 1¼-in. round-hole screen, per cent	81.5	64.5	48.5
Passing ⅝-in. round-hole screen, per cent.	37.5	22.2	8.8
Passing ⅜-in. round-hole screen, per cent.	17.5	20.0	3.5
Specific Gravity........................	2.58	2.58	2.58
Compact Weight, lb. per cu. ft............	113.5	119.5	107.1
Percentage of Voids.....................	30.0	26.0	34.0

It should be noted that in the above report the data on stone is on a commercial size of material, grading No. 1 representing the greatest amount of fine material allowed by the specifications; grading No. 2 having the least amount of fine material allowed by the specifications; and grading No. 3 representing the average limits, as called for under the specifications. The weight determinations on gravel, however, are made on materials graded quite differently than the stone, gradings Nos. 4 and 5 containing a greater amount of fines than would ordinarily be permitted under most specifications. Grading No. 6 corresponds approximately to grading No. 3 in stone.

REPORTED BY F. C. LANG ON SIX DIFFERENT AGGREGATES

Results of weight determinations on seven gradings of six different aggregates were reported by F. C. Lang, Engineer of Tests and Inspection, Minnesota Highway Department, St. Paul, Minn.:

GRADATION OF AGGREGATE

Grading	Percentage Passing Each Screen (Round-Hole Screens)							
	$2\frac{3}{4}$-in.	2-in.	$1\frac{1}{2}$-in.	1-in.	$\frac{3}{4}$-in.	$\frac{1}{2}$-in.	$\frac{1}{4}$-in.	$\frac{1}{8}$-in.
No. 1	..	100	60	20	5	3	2	1
No. 2	..	100	75	30	8	4	2	1
No. 3	..	100	75	40	10	6	2	1
No. 4	100	95	75	50	30	15	4	1
No. 5	100	95	80	60	30	15	5	1
No. 6	100	95	80	70	35	15	8	1
No. 7	100	95	90	80	40	20	10	3

WEIGHT PER CUBIC FOOT

		Trap Rock (Specific Gravity 2.97)	Granite (Specific Gravity 2.653)	Gravel (Specific Gravity 2.63)	Sandstone (Specific Gravity 2.20)	Limestone (Specific Gravity 2.63)	Babbit Rock (Specific Gravity 3.45)
Grading No. 1	Weight per Cubic Foot, lb.	107.4	96.1	105.6	85.3	95.8	117.5
	Percentage of Voids	42.0	41.9	35.6	37.8	41.6	45.4
Grading No. 2	Weight per Cubic Foot, lb.	107.4	96.8	107.6	86.4	97.4	114.2
	Percentage of Voids	42.0	41.5	34.4	37.0	40.6	46.9
Grading No. 3	Weight per Cubic Foot, lb.	107.0	98.2	109.0	87.4	98.4	116.2
	Percentage of Voids	42.2	40.6	33.5	36.3	40.0	46.0
Grading No. 4	Weight per Cubic Foot, lb.	110.4	102.2	110.0	90.0	101.8	118.8
	Percentage of Voids	40.4	38.2	32.9	34.4	37.9	44.8
Grading No. 5	Weight per Cubic Foot, lb.	111.4	103.4	112.5	90.4	102.2	120.0
	Percentage of Voids	39.8	37.5	31.4	34.1	37.7	44.2
Grading No. 6	Weight per Cubic Foot, lb.	112.0	102.7	113.0	91.9	103.3	121.3
	Percentage of Voids	39.5	37.9	31.1	33.0	37.1	43.6
Grading No. 7	Weight per Cubic Foot, lb.	113.5	104.5	113.8	92.2	105.4	122.6
	Percentage of Voids	38.7	36.8	30.6	32.8	35.7	43.0
Average	Weight per Cubic Foot, lb.	109.9	100.6	110.2	89.1	100.6	118.6
	Percentage of Voids	40.7	39.2	32.8	35.1	38.7	44.8

REPORTED BY FRED HUBBARD ON BLAST-FURNACE SLAGS

Results of weight determinations on twelve gradings of eight blast-furnace slags were reported by Fred Hubbard, Consulting Engineer, The Standard Slag Co., Youngstown, Ohio. Weight determinations were made in accordance with the Society's Standard Method of Tests for Unit Weight of Aggregates for Concrete (C 29 - 27):[1]

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 120.

Gradation of Aggregate

Grading	Percentage Passing Each Screen (Round-Hole Screens Except No. 8, which is a Square-Hole Sieve)										
	4-in.	$3\frac{1}{2}$-in.	3-in.	$2\frac{1}{2}$-in.	2-in.	$1\frac{1}{2}$-in.	1-in.	$\frac{3}{4}$-in.	$\frac{1}{2}$-in.	$\frac{1}{4}$-in.	No. 8
No. 1	100	95	..	0	..	..	..	..	..	..	..
No. 2	100	98	..	5	..	..	..	..	..	..	..
No. 3	..	100	..	10	..	..	..	..	..	..	..
No. 4	..	..	100	95	..	0	..	..	..	..	..
No. 5	..	..	100	98	..	5	..	..	..	..	..
No. 6	..	..	..	100	..	10	..	..	..	..	..
No. 7	..	..	..	..	100	95	..	15	..	0	..
No. 8	..	..	..	..	100	98	..	32	..	2	..
No. 9	..	..	..	..	..	100	..	50	..	5	..
No. 10	..	..	..	..	..	..	100	95	25	0	..
No. 11	..	..	..	..	..	..	100	97	50	12	2
No. 12	..	..	..	..	..	..	..	100	75	25	5

Weight Per Cubic Foot, lb.

	Grading No. 1	Grading No. 2	Grading No. 3	Grading No. 4	Grading No. 5	Grading No. 6	Grading No. 7	Grading No. 8	Grading No. 9	Grading No. 10	Grading No. 11	Grading No. 12
Slag A	72	76	73	77	76	77	78	80	81	78	80	80
Slag B	64	65	66	68	67	68	75	77	77	81	84	86
Slag C	70	71	72	70	71	70	71	73	71	72	76	77
Slag D	62	64	61	66	67	68	68	70	69	64	64	62
Slag E	63	65	64	67	69	66	76	78	79	75	79	79
Slag F	67	69	68	64	64	65	68	71	72	71	74	73
Slag G	82	82	81	76	74	73	88	88	89	86	88	87
Slag H	67	65	66	78	79	79	87	90	89	83	84	86
Average	68.4	69.6	68.9	70.7	70.9	70.8	76.4	78.4	78.4	76.3	78.6	78.8

It will be noted that the above report actually covers three distinct commercial sizes of slag. Gradings Nos. 1, 2 and 3 show the results on commercial $2\frac{1}{2}$ to $3\frac{1}{2}$-in. material graded coarse, average and fine within specification limits. Gradings Nos. 4, 5, and 6 show the results of commercial $1\frac{1}{2}$ to $2\frac{1}{2}$-in. material graded coarse, average and fine within specification limits. Gradings Nos. 7, 8 and 9 show the results on commercial $\frac{1}{4}$ to $1\frac{1}{2}$-in. material graded coarse, average and fine within specification limits. Gradings Nos. 10, 11 and 12 show the results on commercial No. 8 to $\frac{3}{4}$-in. material graded coarse, average and fine within specification limits.

Results of weight determinations on two gradings of twenty-four blast-furnace slags and one limestone were also reported by Mr. Hubbard, each result being the average of from two to twelve test results on the particular material under consideration. Weight determinations were made in accordance with the Society's Standard Method of Test for Unit Weight of Aggregate for Concrete (C 29 – 27). This report represents the results of weight determinations made on commercial materials covering periodical investigations for one year:

GRADATION OF AGGREGATE

Grading	Percentage Passing Each Screen (Round-Hole Screens)					
	3-in.	$2\frac{1}{2}$-in.	2-in.	$1\frac{1}{2}$-in.	$\frac{3}{4}$-in.	$\frac{1}{4}$-in.
No. 5	100	98	..	5	..	..
No. 8	..	..	100	98	32	2

WEIGHT PER CUBIC FOOT[a]

	Grading No. 5				Grading No. 8			
	Number of Determinations	Average Specific Gravity	Average Weight per Cubic Foot, lb.	Average Percentage of Voids	Number of Determinations	Average Specific Gravity	Average Weight per Cubic Foot, lb.	Average Percentage of Voids
Slag 2	12[a]	2.19	78.3	42.6	12	2.27	81.8	42.0
Slag 3	11	2.07	74.1	42.4	11	2.08	77	40.6
Slag 4	3	2.05	67.7	47.0	3	2.05	70.7	44.7
Slag 5	9	2.13	72	45.8	9	2.14	73.7	44.8
Slag 7	8	2.05	70.1	45.1	8	2.03	72.9	42.2
Slag 8	8	2.12	73.8	44.1	8	2.15	80.1	40.2
Slag 9	2	2.14	73.5	44.9	2	2.14	75.5	43.3
Slag 10	12	2.10	72.4	44.7	12	2.14	78.1	41.5
Slag 11	12	1.97	68.8	44.0	12	2.01	74.8	40.3
Slag 13	8	2.06	71.5	44.4	8	2.08	77	40.5
Slag 14	5	2.02	68	45.7	5	2.24	83.6	40.1
Slag 15	5	2.18	74.2	45.1	5	2.30	82.6	42.3
Slag 16	8	2.06	71.6	44.0	8	2.12	79.3	40.0
Slag 17	9	1.98	69.7	43.5	9	2.01	73.3	41.2
Slag 18	7	2.12	73.7	44.1	8	2.18	78.1	42.5
Slag 19	9	2.03	69.6	45.1	9	2.10	76.8	41.5
Slag 20	4	1.92	65	45.7	4	1.97	68.8	43.7
Slag 21	6	2.09	79.7	46.5	6	2.11	75.5	42.6
Slag 25	11	2.49	88.6	42.7	11	2.49	92.4	40.4
Slag 26	10	2.63	93	43.2	10	2.62	96.8	40.7
Slag 27	9	2.34	87	40.5	9	2.31	83.2	42.0
Slag 29	9	2.32	85.7	40.5	9	2.35	87	40.6
Slag 31	3	2.37	80.3	45.7	5	2.37	89.3	39.5
Slag 32	7	2.02	70.1	44.3	7	2.11	76	42.2
Average	....	2.14	74.9	44.2	..	2.18	79.3	41.6
imestone	12	2.68	94.8	43.2	12	2.68	99.3	40.5

[a] Detailed data of the individual determinations on each of the twenty-four slags are on file at the Society's headquarters.

The two gradations considered in the above report represent commercial $1\frac{1}{2}$ to $2\frac{1}{2}$-in. size and $\frac{1}{4}$ to $1\frac{1}{2}$-in. size. These gradations representing average commercial specification requirements.

REPORTED BY H. F. GONNERMAN ON SLAG, GRANITE AND PEBBLES

Results of weight determinations were reported by H. F. Gonnerman, Manager, Research Laboratory, Portland Cement Association, Chicago, Ill., on five gradings of slag, granite, and gravel, together with the weights of these materials combined with four different percentages of sand. Weight determinations were made in accordance with the Society's Standard Method of Test for Unit Weight of Aggregate for Concrete (C 29 – 27) except that a $\frac{1}{3}$-cu-ft. cylindrical measure was used having a diameter equal to its height:

GRADING OF COARSE AGGREGATE

Size	Percentage by Weight Retained on Each Sieve (Square-Hole Sieves)									
	No. 100	No. 48	No. 28	No. 14	No. 8	No. 4	$\frac{3}{8}$-in.	$\frac{3}{4}$-in.	$1\frac{1}{2}$-in.	Fineness Modulus
4 to $\frac{3}{8}$-in.	100	100	100	100	100	100	0	0	0	6.00
4 to $\frac{3}{4}$-in.	100	100	100	100	100	100	67	0	0	6.67
4 to $1\frac{1}{2}$-in.	100	100	100	100	100	100	75	25	0	7.00
$\frac{3}{8}$ to $\frac{3}{4}$-in.	100	100	100	100	100	100	100	0	0	7.00
$\frac{3}{4}$ to $1\frac{1}{2}$-in.	100	100	100	100	100	100	100	100	0	8.00

WEIGHT PER CUBIC FOOT FOR DIFFERENT PERCENTAGES OF SAND, LB.

Aggregate		Weight per Cubic Foot for Different Percentages of Sand, lb.					
Sand	Coarse Aggregate	0 per cent Sand	20 per cent Sand	40 per cent Sand	60 per cent Sand	80 per cent Sand	100 per cent Sand
SAND AND SLAG AGGREGATE							
0 to No. 4	4 to $\frac{3}{8}$-in.	90	101	113	118	114	115
	4 to $\frac{3}{4}$-in.	93	110	125	124	122	115
	4 to $1\frac{1}{2}$-in.	95	114	122	124	122	115
	$\frac{3}{8}$ to $\frac{3}{4}$-in.	91	107	109	122	124	115
	$\frac{3}{4}$ to $1\frac{1}{2}$-in.	91	103	118	123	123	115
		—	—	—	—	—	—
	Average	92	107	117	122	121	115
SAND AND GRANITE AGGREGATE							
0 to No. 4	4 to $\frac{3}{8}$-in.	96	100	110	119	117	115
	4 to $\frac{3}{4}$-in.	97	108	117	120	119	115
	4 to $1\frac{1}{2}$-in.	99	112	123	126	122	115
	$\frac{3}{8}$ to $\frac{3}{4}$-in.	96	112	121	123	120	115
	$\frac{3}{4}$ to $1\frac{1}{2}$-in.	96	115	126	127	123	115
		—	—	—	—	—	—
	Average	97	109	119	123	120	115
SAND AND PEBBLE AGGREGATE							
0 to No. 4	4 to $\frac{3}{8}$-in.	105	115	121	120	119	115
	4 to $\frac{3}{4}$-in.	109	121	130	125	120	115
	4 to $1\frac{1}{2}$-in.	111	123	130	127	126	115
	$\frac{3}{8}$ to $\frac{3}{4}$-in.	105	122	128	126	124	115
	$\frac{3}{4}$ to $1\frac{1}{2}$-in.	105	121	135	132	125	115
		—	—	—	—	—	—
	Average	107	120	129	126	123	115

Respectfully submitted on behalf of the section,

FRED HUBBARD,
Chairman.

APPENDIX VIII

THE EFFECT OF ADMIXTURES ON THE WATER-CEMENT RATIO-STRENGTH RELATION OF CONCRETE

By George Conahey[1]

There have been considerable data presented before the various technical societies to show the effect of admixtures on the strength, permeability and other physical properties of the concrete. With the increased application of the water-cement ratio laws to concrete proportioning the effect of admixtures upon the water-cement ratio - strength relation of the concrete is an important question. The data presented by Pearson and Hitchcock in 1924[2] and the data presented by D. A. Abrams in 1920[3] have been used in the study for this report. These two papers are very complete reports on the effect of admixtures in concrete.

The data of Pearson and Hitchcock's paper are plotted in Fig. 1. These data show that, when 10 per cent of hydrated lime, 6⅔ per cent of kaolin or 3⅓ per cent of Celite by weight of the cement were used as admixtures, the water-cement ratio - strength relation of the concrete were changed and a larger quantity of mixing water can be used and the same strength obtained. In other words, for a given strength, more water can be used in mixing concrete containing these admixtures than can be used with a concrete without admixtures.

A study of these curves shows that the extra quantity of water which may be added to a concrete containing these admixtures without reducing the strength is approximately as follows:

0.03 cu. ft. per bag of cement with 6⅔ per cent of kaolin as admixture.
0.05 " " " " " " " 10 per cent of lime as admixture.
0.10 " " " " " " " 3⅓ per cent of Celite as admixture.

The admixtures of the calcium chloride type had very little effect upon the strength relation at the higher water ratios (lean mixes) but with the lower water ratios (rich mixes) the relation is above the plain concrete of the same water ratio. This curve is not shown in Fig. 1.

The data presented by D. A. Abrams, Fig. 2, show similar results as those obtained by Pearson and Hitchcock when similar quantities of admixtures were used. When excessive quantities of these materials were added the strength of the concrete was reduced at the same water ratio. A study of the curves of

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[1] Research Engineer, The Celite Products Co., Washington, D. C.

[2] J. C. Pearson and F. A. Hitchcock, "Economic Value of Admixtures," *Proceedings*, Am. Concrete Inst., Vol. XX, p. 312 (1924).

[3] D. A. Abrams, "Effect of Hydrated Lime and Other Powdered Admixtures in Concrete," *Proceedings*, Am. Soc. Testing Mats., Vol. XX, Part II, p. 149 (1920).

Abrams' data shows that the extra quantity of mixing water which may be added with these admixtures without reducing the strength is as follows:

0.03 cu. ft. per bag of cement with 5 per cent of kaolin as admixture.
0.02 " " " " " " " 4.2 per cent of lime as admixture.
0.07 " " " " " " " 2.8 per cent of Kieselguhr as admixture.

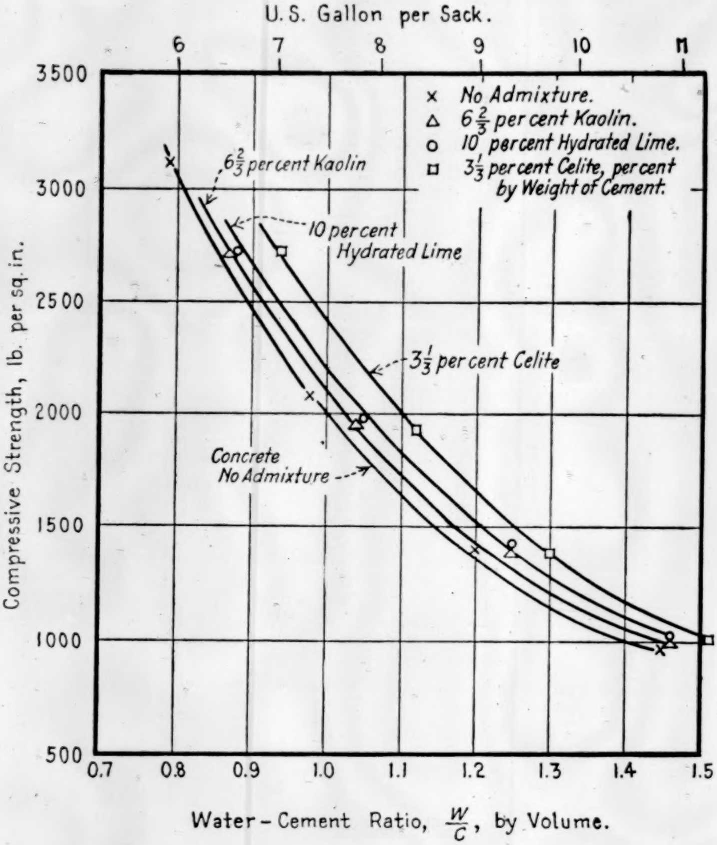

FIG. 1.—Showing Economic Value of Admixtures.

Plotted from data appearing in paper by J. C. Pearson and F. A. Hitchcock, "Economic Value of Admixtures," *Proceedings*, Am. Concrete Inst., Vol. XX, p. 312 (1924).

In a paper by Abrams presented before the Society in 1924,[1] conclusion 10 reads as follows: " . . . The water-ratio – strength curves for 2 per cent of commercial calcium chloride were similar in form but divergent at the lower water ratios, showing the greater effect of the calcium chloride on the richer mixes and drier concretes." This curve is not shown in Fig. 2.

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In conclusion, the data in these two reports show the importance of determining the water-cement ratio - strength relation of the materials that are to be used on the job if the concrete is to be designed for strength by the water-cement ratio laws. If admixtures are to be used on the job they should be used in the tests to determine the water-cement ratio - strength relation that is used to design the concrete.

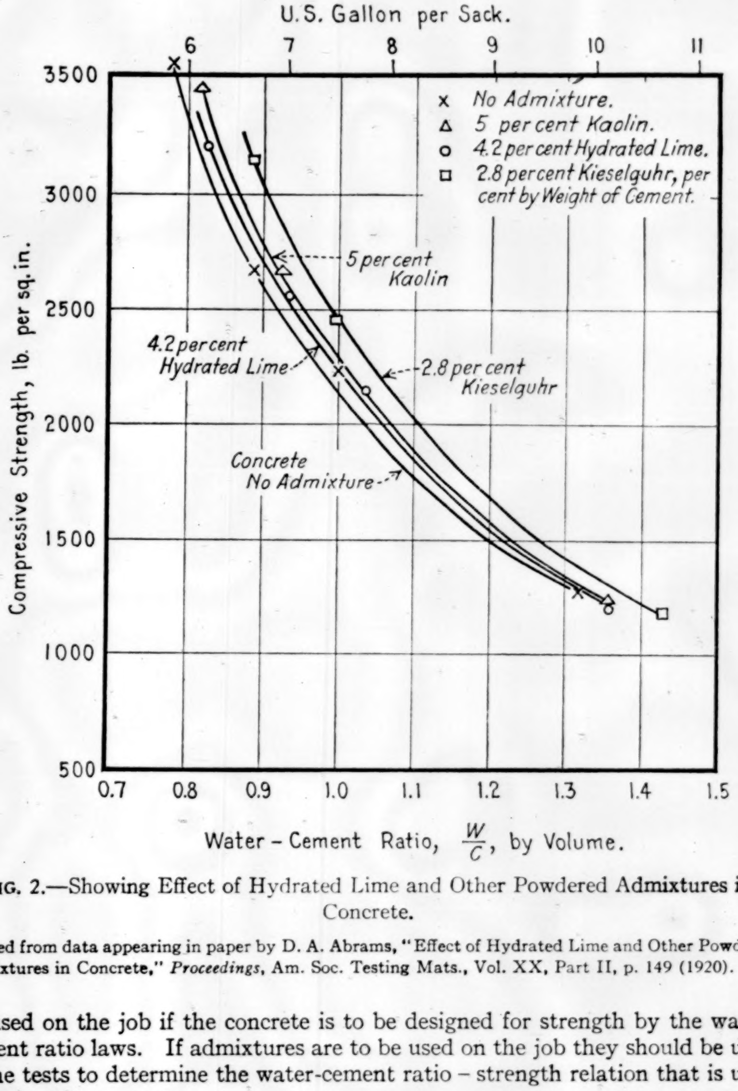

FIG. 2.—Showing Effect of Hydrated Lime and Other Powdered Admixtures in Concrete.

Plotted from data appearing in paper by D. A. Abrams, "Effect of Hydrated Lime and Other Powdered Admixtures in Concrete," *Proceedings*, Am. Soc. Testing Mats., Vol. XX, Part II, p. 149 (1920).

REPORT OF SUB-COMMITTEE XVI ON ELASTICITY AND VOLUME CHANGES OF CONCRETE

After the reorganization of the Sub-Committee on Elasticity and Volume Changes of Concrete last June, it was decided that the first work to be undertaken should be a survey and a critical study of available information on the subjects assigned to the sub-committee. The work may be classed under three divisions:

1. *Preparation of Bibliographies.*—Bibliographies have been prepared and are appended hereto on four general topics, I, Modulus of Elasticity and Stress-Strain Relations of Concrete; II, Poisson's Ratio for Concrete; III, Inelastic Deformation or Plastic Flow of Concrete; and IV, Volume Changes Due to Temperature and Moisture Variations in Concrete. In addition to the work of the members of the sub-committee, especial acknowledgment is made to Mr. Albert Cleve of the Portland Cement Association, Chicago, Ill., and to Mr. E. R. Dawley of Kansas State Agricultural College, Manhattan, Kans., for assistance in the preparation of these bibliographies.

2. *Study of Test Methods.*—A study of methods of test involving the measurement of deformations of concrete due to various causes is now under way and it is planned to prepare summaries relating to items, such as, kind of test, type of specimen, details of apparatus, precision of measurement and variability of the properties determined.

3. *Sponsoring of Research Papers.*—Various members of the sub-committee are carrying on investigations that should eventually lead to papers to be presented before the Society. In addition, it is believed that the activities of the sub-committee should stimulate interest in its field and thus lead to an increase in research along well-defined and worth-while lines.

This report has been submitted to letter ballot of the sub-committee, which consists of 7 members, all of whom have voted affirmatively.

Respectfully submitted on behalf of the sub-committee,

F. E. Richart,
Chairman.

APPENDIX IX

BIBLIOGRAPHIES ON MODULUS OF ELASTICITY, POISSON'S RATIO, INELASTIC DEFORMATION AND VOLUME CHANGES OF CONCRETE

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REPORT OF COMMITTEE C-10

ON

HOLLOW MASONRY BUILDING UNITS

Committee C-10 has held two meetings during the past year. Much interest has been shown in proposals relating to standard designs and sizes of hollow tile and in the development of specification requirements that have a direct bearing on the fire-resistive properties of the individual units. The committee is submitting tentative revisions relating to these subjects but desires to make a further survey of the industry before revising the existing standards.

The results of an investigation of the fire resistance of hollow tile masonry, conducted at the U. S. Bureau of Standards, form the basis for the proposed tentative revision of the absorption requirements. In the fire tests, the overburned dense tiles generally showed a greater tendency to crack and spall than the normally-burned but otherwise similar units. One of the walls tested was built with shale tiles selected to give a wide range in their hardness of burning. The individual tiles in this wall ranged in absorption from 1.4 to 10.3 per cent. During the test, which was continued for one hour and 32 minutes, holes formed in the exposed shells of some of the units having absorptions less than 4 per cent, whereas no spalling was noted on those having absorptions greater than 6 per cent. The fire resistance period of this wall was limited by flame passage through openings caused by the spalling of the overburned tiles before the period based on the temperature rise of the unexposed face was reached. It appears desirable to place a minimum limit on absorption in order to give a fair assurance that the presence of unduly hard-burned tiles will not cause the fire resistance periods to be considerably less than the values specified in the Standard Specifications and Tests for Hollow Burned-Clay Load-Bearing Wall Tile (C 34 – 27).[1] The proposed tentative revision imposes a minimum requirement of 5 per cent for the absorption of the tiles of a test sample.

In line with the committee's policy of reducing the number of different types of units when practicable, it is proposed to eliminate the 8 by 5 by 12-in. two-cell unit and the 12 by 12 by 12-in. 6-cell unit from Specifications C 34 – 27. These specifications now provide for two different types for each of these sizes. The test data now available indicate that, for the 8 by 5 by 12-in. size, walls built of the 3-cell units are superior in strength and fire resistance to those built with the 2-cell units. The 6-cell 12 by 12 by 12-in. units may be laid improperly so as to give but two cells through the thickness of a wall without detection by an inspection of the finished structure. Since the production of units of this size is relatively small, it is believed that the 9-cell unit, which is not open to this objection, will meet the needs of the industry.

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 213.

PROPOSED REVISIONS OF STANDARD SPECIFICATIONS

The committee recommends the following as tentative revisions of the standard specifications for hollow tile:

Standard Specifications and Tests for Hollow Burned-Clay Load-Bearing Wall Tile (C 34 - 27):[1]

Section 2 (*a*).—Change the wording and the absorption requirements of this section from the present form: namely,

2. (*a*) According to the results of physical tests, tile shall be classified as Hard, Medium and Soft on the basis of the following strength and absorption requirements, both of which must be met for a given class:

Class	Absorption, per cent		Compressive Strength Based on Gross Area, lb. per sq. in.			
			End Construction		Side Construction	
	Mean of 5 Tests	Individual Maximum	Mean of 5 Tests	Individual Minimum	Mean of 5 Tests	Individual Minimum
Hard	12 or less	15	2000 or more	1400	1000 or more	700
Medium	16 or less	19	1400 or more	1000	700 or more	500
Soft	25 or less	28	1000 or more	700	500 or more	350

to read as follows:

2. (*a*) According to the results of the physical tests, tile shall be classified as Hard, Medium and Soft on the basis of the following strength and absorption requirements, the class of any lot being determined by the requirement which gives it the lowest rating:

Class	Absorption, per cent			Compressive Strength Based on Gross Area, lb. per sq. in.			
				End Construction		Side Construction	
	Mean of 5 Tests	Individual Maximum	Individual Minimum	Mean of 5 Tests	Individual Minimum	Mean of 5 Tests	Individual Maximum
Hard	6 to 12	15	5	2000 or more	1400	1000 or more	700
Medium	12 to 16	19	5	1400 or more	1000	700 or more	500
Soft	16 to 25	28	5	1000 or more	700	500 or more	350

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 213.

Section 3 (a).—It is recommended that the 2-cell 8 by 5 by 12-in. unit weighing 16 lb. and the 6-cell 12 by 12 by 12-in. unit weighing 48 lb. be eliminated from the table of weights.

Standard Specifications and Tests for Hollow Burned-Clay Floor Tile (C 57 - 27):[1]

Section 2 (a).—Change the wording and the absorption requirements of this section from their present form: namely,

2. (*a*) According to the results of physical tests, tile shall be classified as Hard, Medium and Soft on the basis of the following strength and absorption requirements, both of which must be met for a given class:

Class	Absorption, per cent		Compressive Strength Based on Net Area, lb. per sq. in.			
	Mean of 5 Tests	Individual Maximum	End Construction		Side Construction	
			Mean of 5 Tests	Individual Minimum	Mean of 5 Tests	Individual Minimum
Hard	12 or less	15	4600 or more	3000	2400 or more	1700
Medium	16 or less	19	3200 or more	2250	1600 or more	1100
Soft	25 or less	28	2000 or more	1400	1200 or more	850

to read as follows:

2. (*a*) According to the results of the physical tests, tile shall be classified as Hard, Medium and Soft on the basis of the following strength and absorption requirements, the class of any lot being determined by the requirement which gives it the lowest rating:

Class	Absorption, per cent			Compressive Strength Based on Net Area, lb. per sq. in.			
	Mean of 5 Tests	Individual Maximum	Individual Minimum	End Construction		Side Construction	
				Mean of 5 Tests	Individual Minimum	Mean of 5 Tests	Individual Minimum
Hard	6 to 12	15	5	4600 or more	3000	2400 or more	1700
Medium	12 to 16	19	5	3200 or more	2250	1600 or more	1100
Soft	16 to 25	25	5	2000 or more	1400	1200 or more	850

PROPOSED REVISIONS OF TENTATIVE SPECIFICATIONS

Tentative Specifications and Tests for Hollow Burned-Clay Fireproofing, Partition and Furring Tile (C 56 - 27 T).[2]—The following revisions are recommended, the specifications as revised being continued as tentative:

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 219.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 841 (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 286.

Section 2 (a).—Make the same change as in Section 2 (*a*) of Standard Specifications C 57 – 27, above.

The committee has re-elected the present officers to serve for the ensuing term of two years.

The foregoing recommendations have been submitted to letter ballot of the committee with the following results:

Items	Affirmative	Negative	Not Voting
I. TENTATIVE REVISION OF STANDARDS			
Standard Specifications and Tests for Hollow Burned-Clay Load-Bearing Wall Tile (C 34 – 27)	18	1	4
Standard Specifications and Tests for Hollow Burned-Clay Floor Tile (C 57 – 27)	18	1	4
II. REVISION OF TENTATIVE STANDARD			
Tentative Specifications and Tests for Hollow Burned-Clay Fireproofing, Partition and Furring Tile (C 56 – 27 T)	18	0	5

This report has been submitted to letter ballot of the committee, which consists of 23 members; 20 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

D. E. PARSONS,
Chairman.

H. D. FOSTER,
Secretary.

EDITORIAL NOTE

The proposed revisions of the Standard Specifications and Tests for Hollow Burned-Clay Load-Bearing Wall Tile; and for Hollow Burned-Clay Floor Tile were accepted for publication as tentative and appear on pages 1123 and 1124, respectively.

The proposed revisions of the Tentative Specifications and Tests for Hollow Burned-Clay Fireproofing, Partition and Furring Tile were accepted. The tentative specifications and tests in their revised form appear on page 859.

REPORT OF COMMITTEE C-11
ON
GYPSUM

Committee C-11 has held three meetings since presenting its last report. They were held at the U. S. Bureau of Standards, Washington, D. C., on November 15 and 16, 1927; at the Mayflower Hotel, Washington, D. C., on March 22, 1928; and at Atlantic City, N. J., in conjunction with the June, 1928, annual meeting of the Society.

Sub-Committee I on Gypsum for Various Uses has been actively engaged in the study of the use of gypsum-anhydrite mixtures as a retarder in portland cement. Unfortunately, no mill tests have been carried out, but laboratory tests have been conducted and reports received from the International Cement Corporation, Lehigh Cement Co. and the Non-Metallic Division of the U. S. Bureau of Mines, New Brunswick Station. The tests conducted indicate that gypsum-anhydrite mixtures act favorably on most of the cements used in the tests. It is proposed to have mill tests run to check up the results of the laboratory tests.

Sub-Committee III on Structural Gypsum Products during the year initiated quite an extensive investigation to be conducted in conjunction with the Bureau of Standards relative to the properties of gypsum fiber concrete. It is hoped with the completion of this work that the values to be used in the design of poured-in-place gypsum construction will be placed upon a more standardized basis.

The following recommendations are made to the Society relative to the tentative standards under the jurisdiction of Committee C-11:

Tentative Specifications for Keene's Cement (C 61 – 26 T).[1]—Committee C-11 recommends that the revised Specifications for Keene's Cement appended hereto[2] replace the Tentative Specifications for Keene's Cement (C 61 – 26 T). The requirements of these specifications are based on values obtained in investigative work on brands of Keene's cement which have been used over a term of years with complete satisfaction.

Tentative Definitions of Terms Relating to the Gypsum Industry (C 11 – 27 T).[3]—Committee C-11 recommends that with the approval of Committee E-8 on Nomenclature and Definitions the definitions of the following terms in the Tentative Definitions C 11 - 27 T be advanced to standard: Gypsum Molding Plaster; Gypsum Pottery Plaster; and Keene's Cement.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, p. 749 (1926); also 1927 Book of A.S.T.M. Tentative Standards, p. 216.

[2] See p. 816.—Ed.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 793 (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 218.

Proposed New Tentative Standard.—Committee C-11 recommends that the proposed Specifications for Calcined Gypsum for Use in the Preparation of Dental Plasters appended hereto[1] be accepted for publication as tentative. These specifications have been prepared based on data developed but not published by several of the members of the committee.

The addition of the following members to the committee has not disturbed the balance of producer and non-producer membership:

Allentown Portland Cement Co., Catasauqua, Pa., represented by W. H. Andrews (non-producer);
H. E. Brookby, Consulting Engineer, Evanston, Ill. (non-producer);
American Gypsum Co., Port Clinton, Ohio, represented by D. W. Griswold (producer).

The committee has re-elected the present officers to serve for the ensuing term of two years.

The recommendations appearing in this report have been submitted to letter ballot of the committee with the following result:

Items	Affirmative	Negative	Not Voting
I. REVISION OF TENTATIVE STANDARD			
Specifications for Keene's Cement (C 61 - 26 T)	25	1	4
II. TENTATIVE STANDARD ADVANCED TO STANDARD			
Definitions of Terms Relating to the Gypsum Industry (C 11 - 27 T)	27	0	3
III. PROPOSED NEW TENTATIVE STANDARD			
Specifications for Calcined Gypsum for Use in the Preparation of Dental Plasters	23	1	6

This report has been submitted to letter ballot of the committee, which consists of 31 members; 30 members returned their ballots, of whom 29 have voted affirmatively, none negatively, and 1 has marked his ballot "not voting."

Respectfully submitted on behalf of the committee,

J. W. GINDER,
Chairman.

H. J. SCHWEIM,
Secretary.

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[1] See p. 819.—ED.

EDITORIAL NOTE

The proposed revision of the Tentative Specifications for Keene's Cement was accepted. The tentative specifications in their revised form appear on page 816.

The tentative definitions of the terms Gypsum Molding Plaster, Gypsum Pottery Plaster and Keene's Cement were approved at the annual meeting and were subsequently adopted by letter ballot of the Society on September 1, 1928. These definitions have been added to the Standard Definitions of Terms Relating to the Gypsum Industry and appear in the 1928 Supplement to Book of A.S.T.M. Standards.

The proposed Specifications for Calcined Gypsum for Use in the Preparation of Dental Plasters were accepted for publication as tentative and appear on page 819.

REPORT OF COMMITTEE D-1
ON
PRESERVATIVE COATINGS FOR STRUCTURAL MATERIALS

Committee D-1 on Preservative Coatings for Structural Materials held one meeting during the year at the Mayflower Hotel, Washington, D. C., on March 22, 1928. Since the last annual meeting, six resignations have been accepted while five new members have been elected, making a total committee membership of 184.

The past year has been a very active one for the committee and much new material is being presented to the Society for approval. The activities of the various sub-committees are presented in detail in their various reports as appended hereto. In consequence of their work the committee is making the following recommendations:

I. Seven new tentative methods of test and one new specification are being submitted;

II. Revisions of five standards are being proposed;

III. The revision of four tentative standards is recommended,

IV. Six tentative specifications are being recommended for advancement to standard.

The recommendations affecting standards and tentative standards are presented first in summarized form, together with an analysis of the letter ballot on each item. They are referred to in greater detail in the reports of the sub-committees directly responsible for them.

I. New Tentative Standards.—The committee submits for publication as tentative the following seven new methods of test and one new specification as appended hereto:[1]

Proposed Method of Test for Alkalinity or Acidity of Pigments, recommended by Sub-Committee VIII;
Proposed Method of Test for Bleeding of Pigments, recommended by Sub-Committee VIII;
Proposed Method of Test for Hygroscopic Moisture (and Other Matter Volatile Under the Test Conditions) in Pigments, recommended by Sub-Committee VIII;
Proposed Method of Test for Oil Absorption of Pigments, recommended by Sub-Committee VIII;
Proposed Methods of Test for Mass Color and Tinting

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[1] See pp. 877-887, 910-914, and 872, respectively.—Ed.

Strength of Pigments, recommended by Sub-Committee VIII;

Proposed Method of Routine Analysis of Dry Cuprous Oxide, recommended by Sub-Committee VIII;

Proposed Method of Routine Analysis of Dry Mercuric Oxide, recommended by Sub-Committee VIII; and

Proposed Specifications for the Toxic Ingredients in Anti-Fouling Paints, recommended by Sub-Committee XXIII on Anti-Fouling Paints (A. M. Muckenfuss, chairman),

II. Tentative Revisions of Standards.—The committee recommends that the following two standards be revised as given in detail in the reports of the sub-committees appended hereto and be continued as standard; the committee accordingly asks for the necessary nine-tenths vote:

Specifications for Raw Linseed Oil (D 234 – 27), recommended by Sub-Committee V; and

Methods of Routine Analysis of Dry Red Lead (D 49 – 27), recommended by Sub-Committee VIII.

It further recommends that the revision of the following standards be accepted for publication as tentative as given in detail in the reports of the sub-committees appended hereto:

Method of Routine Analysis of Titanium Pigments (D 186 – 27), recommended by Sub-Committee VIII;

Method of Test for Coarse Particles in Paint Pigments (D 185 – 27), recommended by Sub-Committee VIII;

Methods of Testing Shellac (D 29 – 25), recommended by Sub-Committee XIII; and

Definitions of Terms Relating to Paint Specifications (D 16 – 24), recommended by Sub-Committee VI.

III. Proposed Revisions of Tentative Standards.—The committee recommends that the proposed revisions of the following four tentative standards, as given in detail in the reports of the sub-committees appended hereto, be accepted, and the specifications and methods, as revised, be continued as tentative:

Specifications for Boiled Linseed Oil (D 260 – 27 T), recommended by Sub-Committee V;

Specifications for Aluminum Powder for Paints (D 266 – 27 T), recommended by Sub-Committee XV;

Specifications for Gold Bronze Powder (D 267 – 27 T), recommended by Sub-Committee XV; and

Methods of Routine Analysis of White Linseed Oil Paints (D 215 – 27 T), recommended by Sub-Committee VIII.

IV. Tentative Standards Advanced to Standard.—The committee recommends that the following six tentative standards be advanced to standard:

- Specifications for Prussian Blue (D 261 - 27 T), revised as recommended by Sub-Committee XV;
- Specifications for Ultramarine Blue (D 262 - 27 T), revised as recommended by Sub-Committee XV;
- Specifications for Chrome Oxide Green (D 263 - 27 T), revised as recommended by Sub-Committee XV;
- Specifications for Commercial Para Red (D 264 - 27 T), revised as recommended by Sub-Committee XV;
- Method of Test for Elasticity or Toughness of Varnishes by Means of Addition of Linseed Oil (D 154 - 26 T) ; and
- Method of Test for Determination of Wax in Shellac ("Machine Made" and Dry-Bleached Refined Shellac) (D 29 - 27 T), revised as recommended by Sub-Committee XIII.

The committee has re-elected the present officers to serve for the ensuing term of two years.

The above recommendations have been submitted to letter ballot of the committee, which consists of 171 members; 46 members returned their ballots. The analysis of the vote of the committee is given in the accompanying table.

Items	Affirmative	Negative	Not Voting
I. NEW TENTATIVE STANDARDS			
Proposed Method of Test for Alkalinity or Acidity of Pigments	32	0	14
Proposed Methods of Test for Bleeding of Pigments	27	2	17
Proposed Methods of Test for Hygroscopic Moisture in Pigments	29	0	17
Proposed Method of Test for Oil Absorption of Pigments	27	2	17
Proposed Methods of Test for Mass Color and Tinting Strength of Pigments	28	1	17
Proposed Routine Analysis of Dry Cuprous Oxide	27	0	19
Proposed Routine Analysis of Dry Mercuric Oxide	27	0	19
Proposed Specifications for the Toxic Ingredients in Anti-Fouling Paints	27	0	19
II. TENTATIVE REVISIONS OF EXISTING STANDARDS			
D 234 - 27. Specifications for Raw Linseed Oil	33	0	13
D 49 - 27. Methods of Routine Analysis of Dry Red Lead	29	0	17
D 186 - 27. Methods of Routine Analysis of Titanium Pigments	29	0	17
D 185 - 27. Method of Test for Coarse Particles in Paint Pigments	30	0	16
D 29 - 25. Methods of Testing Shellac	28	0	18
D 16 - 24. Definitions of Terms Relating to Paint Specifications	34	1	11
III. PROPOSED REVISIONS OF TENTATIVE STANDARDS			
D 260 - 27 T. Specifications for Boiled Linseed Oil	32	0	14
D 266 - 27 T. Specifications for Aluminum Powder for Paints	28	0	18
D 267 - 27 T. Specifications for Gold Bronze Powder	28	0	18
D 215 - 27 T. Methods of Routine Analysis of White Linseed Oil Paints	29	0	17
IV. ADVANCEMENT OF TENTATIVE STANDARDS TO STANDARD			
261 - 27 T. Specifications for Prussian Blue, as revised	27	0	19
D 262 - 27 T. Specifications for Ultramarine Blue, as revised	27	0	19
D 263 - 27 T. Specifications for Chrome Oxide Green, as revised	27	0	19
D 264 - 27 T. Specifications for Commercial Para Red, as revised	27	0	19
D 154 - 26 T. Method of Test for Elasticity or Toughness of Varnishes by Means of Addition of Linseed Oil	34	0	12
D 29 - 27 T. Method of Test for Wax in Shellac	28	0	18

ACTIVITIES OF SUB-COMMITTEES

Appended are reports of the following sub-committees:

Sub-Committee V on Linseed Oil;
Sub-Committee VI on Definitions;
Sub-Committee VII on Accelerated Tests for Protective Coatings;
Sub-Committee VIII on Methods of Analysis of Paint Materials;
Sub-Committee IX on Varnish;
Sub-Committee XIII on Shellac;
Sub-Committee XIV on the Preparation of Iron and Steel Surfaces for Painting;
Sub-Committee XV on Specifications for Pigments Dry and in Oil when Marketed in that Form;
Sub-Committee XXII on Method of the Application of Paint by Spraying.

In these reports the recommendations appearing earlier in this report are presented in greater detail, and results and discussions of investigations being carried out by these sub-committees are given. In addition to the formal sub-committee reports appended, it is reported on behalf of Sub-Committee III on Testing of Paint Vehicles (H. A. Gardner, chairman) that this sub-committee is developing methods of testing tung oil and soya bean oil and pending further report on these methods it is recommended that the Tentative Specifications for Tung Oil (D 12 - 25 T) and for Soya Bean Oil, Raw or Refined (D 124 - 22 T) be continued as tentative.

This report has been submitted to letter ballot of the committee, which consists of 171 members; 46 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

ALLEN ROGERS,
Chairman.

R. L. HALLETT,
Secretary.

EDITORIAL NOTE

The following proposed Methods of Test and Specifications were accepted for publication as tentative and appear on pages 877 to 887, 910 to 914 and 872: Methods of Test for Alkalinity or Acidity of Pigments; Test for Bleeding of Pigments; Test for Hygroscopic Moisture in Pigments; Test for Oil Absorption of Pigments; Test for Mass Color and Tinting Strength of Pigments; Routine

Analysis of Dry Cuprous Oxide; of Dry Mercuric Oxide; and Specifications for the Toxic Ingredients in Anti-Fouling Paints.

The proposed revisions of the Standard Specifications for Raw Linseed Oil and Methods of Routine Analysis of Dry Red Lead were approved at the annual meeting by a nine-tenths vote and were subsequently adopted by letter ballot of the Society on September 1, 1928. The standard specifications and methods as thus revised appear in the 1928 Supplement to Book of A.S.T.M. Standards.

The proposed revision of the Standard Method of Test for Coarse Particles in Paint Pigments in the form of separate methods was accepted for publication as tentative to supersede, when adopted, the present standard method. The tentative methods appear on page 874.

The proposed revisions of the Standard Methods of Routine Analysis of Titanium Pigments, of Testing Shellac, and Definitions of Terms Relating to Paint Specifications, were accepted for publication as tentative and appear on pages 1127, 1128 and 1134, respectively.

The proposed revisions of the Tentative Specifications for Boiled Linseed Oil; for Aluminum Powder for Paints; for Gold Bronze Powder; and Methods of Routine Analysis of White Linseed Oil Paints were accepted. The tentative specifications and methods in their revised form appear on pages 864, 870, 871 and 888, respectively.

The Tentative Specifications for Prussian Blue; for Ultramarine Blue; for Chrome Oxide Green; and for Commercial Para Red were approved at the annual meeting as revised by the committee, and subsequently adopted as standard by letter ballot of the Society on September 1, 1928, and appear in the 1928 Supplement to Book of A.S.T.M. Standards.

The Tentative Method of Test for Elasticity or Toughness of Varnishes by Means of Addition of Linseed Oil; and of Test for Determination of Wax in Shellac ("Machine-Made" and Dry-Bleached Refined Shellac) were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on September 1, 1928, and appear in the 1928 Supplement to Book of A.S.T.M. Standards.

REPORT OF SUB-COMMITTEE V ON LINSEED OIL

At the meeting last June, Standard Specifications for Raw Linseed Oil (D 234 - 27) were adopted and Tentative Specifications for Boiled Linseed Oil (D 260 - 27 T) were accepted for publication. Since that time, a number of comments and criticisms have been received. Several of these refer to the iodine number determination and some to the lack of a requirement for the proper limits and the determination of rosin in boiled linseed oil. Suggestions have been received that physical or film tests be substituted for our present analytical requirements for boiled linseed oil. During the year, these comments have been considered.

RAW LINSEED OIL

Wijs Iodine Number.—The principal criticisms concern the method for the determination of the iodine number in the Standard Specifications for Raw Linseed Oil (D 234 - 27) and in the Tentative Specification for Boiled Linseed Oil (D 260 - 27 T). Variations have been found in the results of determinations by some members of the committee, and these errors were found to be traceable to a lack of concise, specific directions in the method.

The objections are briefly:

1. Too wide a latitude in the weight of sample taken;
2. No statement of the time at which the potassium iodide shall be added to the flask after standing the specified length of time;
3. No statement of the time at which the starch indicator shall be added;
4. The lack of directions for making the solutions used and for their standardization.

Mr. S. O. Sorenson, a member of this sub-committee, has contributed a large number of analytical results, indicating that the potassium iodide should be added just before titrating, and the starch indicator after the yellow color of the solution has almost disappeared.

The sub-committee is undertaking further cooperative work to arrive at conclusions on points 1, 2, and 3. To take care of point 4, the sub-committee recommends that the following revisions be made in the Standard Specifications for Raw Linseed Oil (D 234 - 27)[1] and that the specifications as revised be continued as standard:

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 226.

Under Methods of Testing add a new Section 2 reading as follows and change the present Section 2 to Section 3:

SOLUTIONS REQUIRED

2. The following reagents will be required:

Standard Sodium Hydroxide Solution.—Prepare a stock concentrated solution of sodium hydroxide by dissolving NaOH in water in the proportion of 200 g. of NaOH to 200 cc. of water. Allow this solution to cool and settle in a stoppered bottle for several days. Decant the clear liquid from the precipitate of sodium carbonate into another clean bottle. Add clear barium hydroxide solution until no further precipitate forms. Again allow to settle until clear. Draw off about 175 cc. and dilute to 10 liters with freshly boiled distilled water. Preserve in a stock bottle provided with a large guard tube filled with soda lime. Determine the exact strength by titrating against pure benzoic acid (C_6H_5COOH) using phenolphthalein as indicator. (See U. S. Bureau of Standards *Scientific Paper No. 183.*) This solution will be approximately 0.25 *N*, but do not attempt to adjust it to any exact value. Determine its exact strength and make proper corrections in using it.

Alcoholic Sodium Hydroxide Solution.—Dissolve pure NaOH in 95-per-cent ethyl alcohol in the proportion of about 22 g. per 1000 cc. Let stand in a stoppered bottle. Decant the clear liquid into another bottle, and keep well stoppered. This solution should be colorless or only slightly yellow when used; it will keep colorless longer if the alcohol is previously treated with NaOH (about 80 g. to 1000 cc.), kept at about 50° C. for 15 days, and then distill. For an alternate method see *Journal*, American Chemical Society, 1906, p. 395.

0.5 N Sulfuric Acid Solution.—Add about 15 cc. of H_2SO_4 (sp. gr. 1.84) to distilled water, cool and dilute to 1000 cc. Determine the exact strength by titrating against freshly standardized NaOH or by any other accurate method. Either adjust to exactly 0.5 *N* strength or leave as originally made, applying appropriate correction.

Wijs Iodine Monochloride Solution.—Dissolve iodine in glacial acetic acid that has a melting point of 14.7 to 15° C. and which is free from reducing impurities in the proportion so that 13 g. of iodine will be present in 1000 cc. of solution. The preparation of the iodine monochloride solution presents no great difficulty, but it shall be done with care and accuracy in order to obtain satisfactory results. There shall be in the solution no sensible excess either of iodine or more particularly of chlorine over that required to form the monochloride. This condition is most satisfactorily attained by dissolving in the whole of the acetic acid to be used the requisite quantity of iodine, using a gentle heat to assist the solution, if it is found necessary. The halogen content can be accurately measured by titration of a portion of the solution with 0.1 *N* sodium thiosulfate using the potassium iodide solution (15-per-cent) and the starch indicator as described in Section 3 under the method for the determination of the iodine number. Set aside a small portion of this solution while pure, and pass dry chlorine into the remainder until the halogen content of the solution is doubled. Ordinarily, it will be found that by passing the chlorine into the main part of the solution until the characteristic color of free iodine has just been discharged, there will be a slight excess of chlorine, which is corrected by the addition of the requisite amount of the unchlorinated portion until all free chlorine has been destroyed. A slight excess of iodine does little or no harm, but excess of chlorine must be avoided.

Starch Solution.—Stir up 2 to 3 g. of potato starch or 5 g. of soluble starch with 100 cc. of 1-per-cent salicylic acid solution, add 300 to 400 cc. boiling water, and boil the mixture until the starch is practically dissolved. Dilute to 1 liter.

Potassium Iodide Solution.—Dissolve 150 g. of potassium iodide free from iodate in distilled water and dilute to 1000 cc.

Standard Sodium Thiosulfate Solution.—Dissolve pure sodium thiosulfate in distilled water that has been well boiled to free it from carbon dioxide in the proportion so that 24.83 g. crystallized sodium thiosulfate will be present in 1000 cc. of the solution. It is best to let this solution stand for about two weeks before standardizing. Standardize with pure resublimed iodine. (See Treadwell-Hall, *Analytical Chemistry*, Vol. II, third edition, p. 646.) This solution will be approximately 0.1 *N* and it is best to leave it as it is after determining its exact iodine value, rather than to attempt to adjust it to exactly 0.1 *N* strength. Preserve in a stock bottle with a guard tube filled with soda lime.

Acid Calcium Chloride Solution.—Saturate with calcium chloride a mixture of 90 parts of water and 10 parts of HCl (sp. gr. 1.19).

Section 2.—Delete the description of the Preparation of Wijs Monochloride Solution appearing after the test for Iodine Number.

Color.—To correct a typographical error in the last sentence change "25 cm." to read "2.5 cm."

BOILED LINSEED OIL

Wijs Iodine Number.—There have been several comments concerning the Tentative Specifications for Boiled Linseed Oil (D 260 - 27 T). The criticism on the determination of the iodine number of raw linseed oil, outlined above under points 1, 2, 3 and 4, also apply to boiled linseed oil.

The sub-committee is undertaking further cooperative work to arrive at conclusions on points 1, 2 and 3. To take care of point 4, the sub-committee recommends the following revisions be made in the Tentative Specifications for Boiled Linseed Oil (D 260 - 27 T)[1] and that the specifications as revised be continued as tentative:

Under Methods of Testing, add a new Section 2 to read the same as recommended above in the Standard Specifications for Raw Linseed Oil (D 234 - 27), describing all the solutions there given with the exception of the Acid Calcium Chloride Solution.

Section 2.—Change the present Section 2 to Section 3 and change all the other section numbers accordingly.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 846 (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 300.

Section 8.—Renumber this section making it Section 9 and omit the description of the Preparation of Wijs Iodine Monochloride Solution appearing after the test for iodine number.

Rosin.—No provision has been made either for limiting the percentage of rosin allowable or for determining the amount present. The physical and chemical constants specified will indirectly limit the quantity of rosin to a certain extent, but not with sufficient accuracy. Requests have been sent to the members of the sub-committee for comments upon the amount of rosin allowable, and also methods for its quantitative determination. There have been several more or less conflicting replies. Resinate driers are preferred to the linoleates by some manufacturers who feel that the former class of driers has better solubility and will not "throw out" of solution so easily upon standing. The use of such driers will produce a rosin content of from 1 to 2 per cent in the oil. On this basis, should rosin be permitted, 2 per cent would be a fair value for the maximum quantity allowable.

On the other hand, it can be said that boiled linseed oil should be pure, and should not contain any cheaper materials such as rosin, on account of opening a way for adulteration.

A method for the determination of a small quantity of rosin in boiled linseed oil has been suggested, namely, that given in *Technologic Paper No. 65,* of the U. S. Bureau of Standards, published in 1916. The matter is of sufficient importance to warrant its further discussion, and it is accordingly recommended that the various methods for the determination of small quantities of rosin in linseed oil be the subject of cooperative work during the coming year. This work should consist of rosin determinations on several known oils by one or two methods to be decided upon later.

Film Tests on Boiled Oil.—One of the members of the sub-committee reports that excellent results have been obtained by determining the elasticity and tensile strength of a boiled oil film. He has found that this test is of great advantage in predetermining the suitability of any boiled oil for a specific use. He has offered a method which consists briefly of flowing a mixture of 10 g. of boiled oil mixed with 20 g. of naphtha over an amalgamated tin plate. The film is allowed to dry 48 hours on the plate, then stripped from the plate and allowed to dry 48 hours more with the reverse side exposed. The film so made is cut with a die and stretched in a Suter Modified Yarn Tester, using special jaws. A number of results have been reported, showing the variation in stretch and strength caused by differences in viscosity, acid value and types of driers.

On the other hand, another member of the sub-committee, after considerable experimentation, states that slight imperfections in the films, entirely mechanical, introduced wide inconsistencies in stretch and tensile strength results. The preparation of the films is most tedious and difficult, requiring an inordinate amount of laboratory work.

Various conditions of drying, in all probability have the most marked effect upon the strength of the films. The cost of apparatus will be prohibitive in a large number of places where these methods are in constant use. The time required for determination is also an important factor in rendering the physical testing of films unsatisfactory. Other physical testing methods, such as hardness, toughness, and gloss of films are at present in the stages of development, not as yet in a state to be recommended to the Society.

The fact also must be considered that the various users require entirely different types of boiled linseed oil. Some oils will have a greater body than others, or a better lustre, or, on the other hand, some may more nearly approach a raw linseed oil.

It is recommended that cooperative work be undertaken during the coming year by the members of this sub-committee in an effort to determine the value of various physical tests such as tensile strength, hardness, and toughness.

Time of Drying on Glass.—There have been some objections to the method for the time of drying, to the effect that the conditions of temperature and humidity are too rigidly specified. Further cooperative work on this subject is proposed during the coming year.

Respectfully submitted on behalf of the sub-committee,

R. D. BONNEY,
Chairman.

REPORT OF SUB-COMMITTEE VI ON DEFINITIONS

At the meeting of Committee D-1 held in June, 1927, the title of Sub-Committee VI was changed from Definitions of Terms Used in Paint Specifications to Definitions.

Several years ago this sub-committee recommended tentative definitions for the terms Screen (Sieve), Toughness and Elasticity[1] for publication as tentative revisions of the Standard Definitions of Terms Relating to Paint Specifications (D 16 - 24). These definitions have been submitted to Committee E-8 on Nomenclature and Definitions and they recommend some changes. Committee E-8, through its Sub-Committee on Sieve and Screen, has adopted the following definition of Screen (Sieve) as a standard definition.

Screen (Sieve).—A plate or sheet or a woven cloth, or other device, with regularly spaced apertures of uniform size, mounted on a suitable frame or holder, for use in separating material according to size.

NOTE 1.—The shape and spacing of apertures, size of wires or threads, thickness of plate or sheet, allowable variations and similar properties, should be taken care of in specifications.

NOTE 2.—In mechanical analysis testing work, when not otherwise specified, the term "sieve" shall apply to an apparatus in which the apertures are rectangular, and the term "screen" shall apply to an apparatus in which the apertures are circular.

The sub-committee recommends that Committee D-1 approve this definition as a tentative revision of its present Definition of Screen (Sieve).

The sub-committee recommends that Committee D-1 approve the following definitions to replace the present definitions of Toughness and Elasticity.

Toughness.—That quality of a material which may be measured by the maximum impact which it will withstand without rupture.

Elasticity.—In the case of paint or varnish, that property which allows a film to follow, without rupture, changes in the extent and form of the surface to which it is applied.

During the past year, the sub-committee has submitted to the members of Committee D-1 for any desired revision the present standard definitions for Paint, Pigment, Vehicle, Varnish and Enamel. It has also presented the term "Lacquer" to be defined.

Respectfully submitted on behalf of the sub-committee,

D. W. EDGERLY,
Chairman.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 1100 (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 774.

REPORT OF SUB-COMMITTEE VII ON ACCELERATED TESTS FOR PROTECTIVE COATINGS

Sub-Committee VII held one meeting during the past year, at French Lick Springs. While the sub-committee has apparently been somewhat inactive, there has been a great deal of individual activity on the part of its members, all of it bearing on the future work of the sub-committee.

A year ago, a series of cooperative tests was carried out with the equipment then in use in seven member laboratories. The agreement of results between the laboratories was not satisfactory and the data assembled are useful only as a starting point for further work. This work did, however, stimulate interest, with the result that various new ideas in testing equipment have been evolved during the year. To the chairman it has seemed best to permit such new ideas to take definite form and allow the members to gain experience in handling their new equipment before again setting out on a program of cooperative tests.

More or less progress can be reported on topics that have been under discussion at our meetings. Among these there may be mentioned, in particular:

1. A system for examining test panels, which includes such questions as the proper magnification to use in looking for failures.
2. A standardized form for reporting results.

The immediate plans of the sub-committee are to seek to arrive at some agreement on these topics, with the possibility that, if the time seems propitious for doing so, further cooperative exposure tests will be inaugurated.

Respectfully submitted on behalf of the sub-committee,

H. A. Nelson,
Chairman.

REPORT OF SUB-COMMITTEE VIII ON METHODS OF ANALYSIS OF PAINT MATERIALS

The sub-committee submits the following seven new methods of tests as appended hereto[1] and recommends their acceptance for publication as tentative:

Proposed Method of Test for Alkalinity or Acidity of Pigments;
Proposed Methods of Test for Bleeding of Pigments;
Proposed Methods of Test for Hygroscopic Moisture in Pigments;
Proposed Method of Test for Oil Absorption of Pigments;
Proposed Methods of Test for Mass Color and Tinting Strength of Pigments;
Proposed Routine Analysis of Dry Cuprous Oxide;
Proposed Routine Analysis of Dry Mercuric Oxide.

The sub-committee recommends that the following revisions be made in the Standard Methods of Routine Analysis of Dry Red Lead (D 49 - 27)[2] as indicated below and that the methods, as revised, be continued as standard:

Section 6.—Change the first three sentences from their present form, namely:

> 6. Weigh 1 g. of finely ground sample into a 200-cc. Erlenmeyer flask, add a few drops of distilled water and rub the mixture to a smooth paste with a glass rod flattened on end. Mix in a small beaker 30 g. of c.p. "Tested Purity" crystallized sodium acetate, 2.4 g. of c.p. KI, 10 cc. of water and 10 cc. of 50-per-cent acetic acid; stir until all is liquid, warming gently; if necessary add 2 to 3 cc. of water, cool to room temperature and pour into the flask containing the red lead. Rub with the glass rod until nearly all the red lead has been dissolved; add 30 cc. of water containing 5 or 6 g. of sodium acetate, and titrate at once with decinormal sodium thiosulfate, adding the latter rather slowly and keeping the liquid constantly in motion by whirling the flask.

to read as follows:

> 6. Weigh 1 g. of the finely-ground sample, transfer to a 200-cc. Erlenmeyer flask, add 10 cc. of a mixture of 7 parts by volume of chloroform and 3 parts by volume of c.p. glacial acetic acid; then add as quickly as possible 40 cc. of the "red-lead solution" at room temperature. Rub with the flattened end of a glass rod until nearly all of the red lead has been dissolved; add 30 cc. of water containing 5 or 6 g. of sodium acetate, and titrate at once with 0.1 *N* sodium thiosulfate, adding the latter rather slowly and keeping the liquid constantly in motion by whirling the flask.

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[1] See pp. 877–887, 910–914, respectively.—Ed.

[2] 1927 Book of A.S.T.M. Standards, Part II, p. 316.

Change the second paragraph after *Calculation* from its present form: namely,

> The sodium-thiosulfate solution and the starch solution shall be prepared as follows:

to read as follows:

> The "red-lead solution," the sodium-thiosulfate solution, and the starch solution shall be prepared as follows:

Add the following description of the red-lead solution:

> *Red-Lead Solution.*—Dissolve in a large beaker (about 1.1 liter) 600 g. of c.p. "Tested Purity" crystallized sodium acetate and 48 g. of c.p. KI in about 500 cc. of 25-per-cent acetic acid solution (made by mixing 150 cc. of c.p. glacial acetic acid with 450 cc. of distilled water). Warm the beaker and contents on a steam-bath, stirring occasionally, until a clear solution is obtained. Cool this solution to room temperature, dilute to exactly 1000 cc. with the 25-per-cent acetic acid solution and mix thoroughly. If preferred, the red-lead solution may be prepared separately for each titration, as follows: Dissolve 30 g. of the c.p. "Tested Purity" crystallized sodium acetate and 2.4 g. of c.p. KI in 25 cc. of the 25-per-cent acetic acid solution, warming gently and stirring until a clear solution is obtained. Cool this solution to room temperature, dilute to 40 cc. with the 25-per-cent acetic acid solution, and mix thoroughly.

The sub-committee also recommends that the following revisions of the Standard Methods of Routine Analysis of Titanium Pigments (D 186 - 27)[1] be accepted for publication as tentative:

Change the central heading of Section 3 from "Color Strength" to read "Tinting Strength."

Add a new Section 10 to read as follows, renumbering the present Sections 10, 11 and 12 to Sections 11, 12 and 13, respectively:

CALCIUM SULFATE

(In the case of Titanium-Calcium Pigments)

10. Transfer 0.5 g. of the pigment to a 250-cc. beaker, add 25 cc. of HCl (1:1), cover with a watch-glass, and boil several minutes. Dilute to 150 cc. with water, heat to boiling, wash off the cover glass, filter through a 9-cm. filter paper, and wash the paper and residue with hot 1-per-cent HCl (prepared by mixing 10 cc. of HCl (sp. gr. 1.19) with 990 cc. of water) until the washings show no calcium when tested with NH_4OH and $(NH_4)_2C_2O_4$. To the filtrate, add 2 drops of concentrated HNO_3 and boil to insure oxidation of the iron. Add NH_4OH until slightly alkaline, and heat to boiling. Then without filtering, add an excess (30 to 35 cc.) of a hot saturated solution of $(NH_4)_2C_2O_4$, stir, and continue the boiling until the precipitate becomes granular. Let stand on a steam bath for one hour, and filter through a 9-cm. filter paper. Wash the beaker and filter with boiling-hot water until 10 cc. of the washings are not decolorized in 2 to 3 minutes after adding 0.5 cc. of H_2SO_4, heating to about

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 341.

70° C., and adding 2 drops of 0.1 *N* $KMnO_4$ solution. Place the beaker in which precipitation was made under the funnel, pierce the apex of the filter paper with a stirring rod and wash the precipitate into the beaker with a jet of hot water; pour 30 cc. of warm dilute H_2SO_4 (1:3) through the filter so that the acid comes in contact with all of the paper, and wash the funnel and filter thoroughly with hot water. Dilute to about 250 cc. with water, heat to about 90° C., and titrate at once with 0.1 *N* $KMnO_4$ solution to a faint pink color that does not disappear in 2 to 3 minutes (the temperature of the solution should not be below 60° C. when the end point is reached). Calculate the total calcium to percentage of $CaSO_4$ (1 cc. of 0.1 *N* $KMnO_4$ is equivalent to 0.0068 g. $CaSO_4$ or 0.0028 g. CaO. The Fe value of $KMnO_4 \times 0.502 =$ CaO value).

The sub-committee submits a complete revision of the Standard Method of Test for Coarse Particles in Paint Pigments (D 185 - 26)[1] in the form of a new proposed method of test as appended hereto.[2] This revision involves the addition of a method for the determination of coarse particles in metallic aluminum and bronze powders and a complete procedure for water-soluble pigments, pastes in oil and in japan, enamels, ship-bottom paints and cellulose ester lacquers. The sub-committee recommends that this proposed method be accepted for publication as a tentative standard to replace when adopted the present Standard Method D 185.

The sub-committee further recommends that the Tentative Methods of Routine Analysis of White Linseed Oil Paints (D 215 - 27 T)[3] be revised as follows and continued as tentative:

In the section on Nature of Thinner under Methods, in order to make the reference to Standard Methods D 233 more specific, insert after the words "described in" the phrase "Sections 6 to 11, inclusive, of."

In the section on Insoluble Matter under Analysis of Pigment make the reference to Standard Methods D 186 more specific by adding after the words "described in" the phrase "Sections 8, 10 and 11 of."

Change the description of test for carbon dioxide under Analysis of Pigment from its present form: namely,

Carbon Dioxide.—Determine by evolution with dilute acid and absorption in soda lime or KOH solution. The method given in U. S. Geological Survey *Bulletin 700*, p. 218, shows a convenient apparatus for carrying out this determination. Use from 1 to 2 g. of the pigment, depending upon the probable CO_2 content, following the method for the determination of carbon dioxide in lime described in the Tentative Methods of Chemical Analysis of Limestone,

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 286.

[2] See p. 874.—ED.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 873 (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 344.

Quicklime and Hydrated Lime (Serial Designation: C 25 - 27 T) of the American Society for Testing Materials (Note 18).

to read as follows:

Carbon Dioxide.—Use from 1 to 2 g. of the pigment depending upon the probable CO_2 content, following either of the methods described under the Determination of Carbon Dioxide in the Tentative Methods of Chemical Analysis of Limestone, Quicklime and Hydrated Lime (Serial Designation: C 25 - 27 T) of the American Society for Testing Materials (Note 18).

Respectfully submitted on behalf of the sub-committee,

F. W. SMITHER,
Chairman.

REPORT OF SUB-COMMITTEE IX ON VARNISH

Several years ago the work of the sub-committee was assigned to a number of working groups. To one of these, Group 6, under the chairmanship of H. A. Nelson, was assigned the determination of acid value and its interpretation. In the report of the sub-committee for 1926[1] six methods of determining acid number were outlined, together with the results of some cooperative tests using these various methods. As a result of the work, the opinion of the operators is that methods III, V and VI give sharper end points and more accurate results than do methods I, II and IV. Methods I and II are those now prescribed in the present Tentative Specifications for Soya Bean Oil, Raw or Refined (D 124 - 22 T) and in Tentative Specifications for Raw Tung Oil (D 12 - 25 T). The sub-committee suggests that the other sub-committees concerned in the determination of acid value reconsider this subject in the light of the results obtained and, if possible, agree upon a universally acceptable method.

Group 6 is planning further cooperative work, using methods III, IV and VI and with four types of varnish, classified according to the gum present, as follows: esterized Congo, lime-treated rosin, zinc-treated rosin and amberal.

Group 4 on Standardization of Service Tests for Exterior Varnishes (H. A. Gardner, chairman) has carried out further tests preliminary to preparing a standard method of exposure tests for varnishes. In the report of the sub-committee for 1926 mention was made of some exposure tests in which the varnish was spread upon panels of glass, wood, black iron and black japanned steel. These tests indicated that the black japanned steel and black iron panels gave the more consistent results and the glass and wood panels were eliminated. A series of tests has since been carried out in which varnish was applied to plated surfaces of nickel and chromium. These tests showed that such surfaces are unsuitable because of early and excessive peeling. Baked enamel surfaces using lower baking temperatures than those previously employed gave better results than were obtained when the varnish was applied to japanned steel, the japan having been baked at 350° F. or higher. The varnish coating in all cases was air dried. The group now feels that it is in a position to prepare a method of exposure test and expects to proceed with this in the near future.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, p. 342 (1926).

A new group has been organized to carry out a series of tests to determine the behavior of the new quickly-drying types of varnish when examined for elasticity or toughness by the Kauri reduction test.

The sub-committee has given consideration to definitions for the terms "varnish" and "enamel" submitted to it by Sub-Committee VI on Definitions. The sub-committee recommends that the term "varnish" should be so defined as to exclude nitro-cellulose lacquer.

The Tentative Method of Test for Elasticity or Toughness of Varnishes by Means of Addition of Linseed Oil (D 154 – 26 T) is being recommended for advancement to standard to be added to the present Standard Methods of Testing Oleo-Resinous Varnishes (D 154 – 25).

Respectfully submitted on behalf of the sub-committee,

E. J. COLE,
Chairman.

K. J. HOWE,
Secretary.

REPORT OF SUB-COMMITTEE XIII ON SHELLAC

The sub-committee has carried on some work to develop a method for determining orpiment in orange shellac but nothing definite has been arrived at to submit at this date.

Considerable research work of value is being carried on. The Research Bureau, established by the U. S. Shellac Importers' Association, has started to function within the past few months and the progress made so far shows indication of producing important results within the present year. This indicates that the shellac industry has at last realized the importance and need of a thorough chemical study of shellac.

The sub-committee offers the following recommendations:

Standard Methods of Testing Shellac (D 29 - 25).[1]—The following revisions of the Standard Method of Testing Shellac are recommended for publication as tentative:

Section 1.—Add to the present note to this section a new paragraph to read as follows:

NOTE.—An 8-in. glass condenser may be substituted for the metal condenser, the stem perforated with 2 holes, from which the siphon is suspended by wire. The condenser is fitted to the neck of the flask (same size and type as described by the method) with a cork stopper. A free flow of cooling water should be maintained during extractions. The use of an Allihin condenser for extractions (with bulbs) is recommended.

Section 3.—Change the second paragraph of this section to read as follows by the addition of the italicized words and the omission of those in brackets:

Dry in an air bath at 105° C., transfer to a glass-stoppered weighing bottle, cool and weigh. Dry to constant weight. A number of cartridges can be prepared and kept in glass-stoppered weighing bottles until wanted. Now weigh 5 g. of the lac in a [100] *200*-cc. *tall* beaker and dissolve in [75] *100–120* cc. of boiling [95-per-cent] alcohol, [by immersing] *immerse* the beaker in a hot water bath, [until] *in order to be certain* all the shellac is dissolved and the wax is in solution. *Alcohol and shellac mixture should be brought to a brisk boil and maintained for 30 minutes at or near the boiling point.* Transfer this solution quickly into the weighed extraction cartridge, previously wet with hot alcohol, putting the cartridge into a carbon filter tube of suitable size supported in a hot water bath (Fig. 2), the outlet tube extending through the bottom of the bath allowing the escape of the filtrate. Wash all the residue from the beaker into the cartridge with hot 95-per-cent alcohol. Put the cartridge in the extraction apparatus (Fig. 1), and extract [for exactly] *to constant weight, in no case less than* one hour.

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 292.

Tentative Method of Test for Determination of Wax in Shellac ("Machine-Made" and Dry-Bleached Refined Shellac) (D 29 - 27 T).[1] —The sub-committee recommends the advancement to standard of the present Tentative Method of Test for Determination of Wax in Shellac with the following correction:

Section 1.—Change the fourth sentence to read as follows by the addition of the italicized words and the omission of those in brackets:

> The wax will [form a layer at] *come to* the top, *solidify as a layer or float as small hard particles according to the amount of wax present in the lac.*

The method of test is to be added to the present Standard Methods of Testing Shellac (D 29 - 25), when the Book of Standards is next issued.

Tentative Methods of Testing Shellac Varnish (D 214 - 27 T).[2]— The sub-committee recommends three corrections in these tentative methods of test:

Section 6.—In Paragraph (*b*), change the percentage of body from 42.45 per cent to 42.47 per cent.

In the second sentence of Paragraph (*c*), change the Centigrade temperature from 16° C. to 15.5° C. to correspond with the Fahrenheit equivalent, 60° F.

Under the Determination of Wax, reference should be made to the Method of Test for Determination of Wax in Shellac ("Machine-Made" and Dry-Bleached Refined Shellac) (D 29 - 27 T), which method is being recommended for advancement to standard.

Respectfully submitted on behalf of the committee,

JOHN W. PAISLEY,
Chairman.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 869 (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 340.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 862 (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 333.

REPORT OF SUB-COMMITTEE XIV ON PREPARATION OF IRON AND STEEL SURFACES FOR PAINTING

Sub-Committee **XIV** reports a further inspection of the test panels exposed at Altoona, Pa., which, with the exception of four reprepared panels, had been exposed, up to the date of inspection, November 10, 1927, for 10 years and about 9 months. The results of this inspection are given in descriptions and tabulations appended hereto. There are also presented reproductions of photographs of the reprepared panels and of several typical original panels, all taken on November 29, 1927, through the agency of Mr. McDonnell.

The outstanding features of the tests as revealed by the last inspection seem to be the following:

1. The good preservation of certain sandblasted and pickled panels at Altoona for periods of 9 to nearly 11 years.

2. The superior preservation, at Altoona, of the sandblasted and pickled surfaces on the original new steel panels and of the sandblasted section on reprepared panel No. 10(*a*). (This superiority did not show for the one sandblasted panel of old steel in the Altoona tests. The recently reprepared panels Nos. 1, 2 and 3 had been exposed only 2 years, which was not long enough to produce conclusive results.)

3. The contradictory results of the Altoona and Brooklyn tests. In the Brooklyn tests the duration of good preservation was shorter than might have been anticipated and the panels which were not sandblasted or pickled were preserved as long generally as those which were so treated. The differences in atmosphere and in exposure to mechanical injury from wind-blown particles at the two locations are factors to be considered in explanation of this difference in results.

4. Panels Nos. 10 and 10(*a*) indicate the need for more thorough cleaning methods than simple wire brushing as a surface preparation where maximum protective coating durability is desired on badly rusted surfaces. Reprepared panel No. 1 gives promise of confirmation of this evidence.

It is believed that up to the time of last inspection all the Altoona panels have continued to give information of value. At that time it was found that all except the reprepared panels and original panels Nos. 6, 8 and 11 had deteriorated beyond what might be considered the condition of good preservation, which the sub-committee thought might be limited by the rating of 80 per cent, and it was decided that with these exceptions the panels might be removed and scrapped. Mr. McDonnell advised later, however, that he will not have any of the panels removed until after the next inspection which he assumed would be made sometime during the year 1928.

Unless otherwise instructed, the sub-committee will therefore continue to make inspections and reports on the Altoona panels.

Respectfully submitted on behalf of the sub-committee,

A. W. CARPENTER,
Chairman.

APPENDIX

The inspection on November 10, 1927, was made by Messrs. M. E. McDonnell, R. E. Rogers and A. W. Carpenter, members of the sub-committee; Mr. F. M. Waring, Engineer of Tests of the Pennsylvania System and Mr. J. E. Gearhart, past-president of the American Railway Association Master Painters' Division. The last named person was commissioned by sub-committee member Mr. A. H. Sabin, who was unable to attend, as his representative in the rating of panels.

Original panels Nos. 1, 2 and 3 were reprepared on October 15, 1925 and re-exposed on October 26, 1925, as noted in the sub-committee report for 1926. The three sections of each of these panels, as re-prepared, are designated by letters at the top of the panel and respective sections, as follows:

WBG, designating the section cleaned with wire brush and washed with benzine which was then burned off.

WB, designating the section wire brushed and dusted off with no further treatment.

SB, designating the section sandblasted.

The characteristics and ratings of these three reprepared panels were as follows:

Panel No. 1.—The surface was rough, due to the uneven corrosion of the surface of the original panel; this roughness or unevenness of surface was most marked over the sandblasted section, less so over the *WBG* section and smoothest over the *WB* section. The paint had a good even color with a few broken points in form of rust blisters except on the sandblasted section which was quite free from breaks.

Panel No. 2.—The surface was smoother than that of Panel No. 1 and about the same over all sections. The color was good and even. There were fewer breaks in the coating than in No. 1.

Panel No. 3.—The surface of this panel was perfectly smooth all over and the color even and good. There were practically no breaks in the coating anywhere.

The ratings of these three reprepared panels were as follows:

Panel	Original Condition and Treatment in 1917	Section as Reprepared in October, 1925	Condition Rating, per cent	
			November 10, 1927	October 15, 1925 (as originally prepared)
No. 1	New steel panel with clean surface, mill scale intact, painted, with no surface treatment, in warm dry room.	SB	98	10
		WB	85	
		WBG	90	
No. 2	New steel panel, mill scale broken, some rust and grease; hand cleaned with benzine, scraper and wire brush; painted in warm dry room.	SB	98	25
		WB	95	
		WBG	95	
No. 3	New steel panel; sandblasted and painted immediately after in warm dry room.	SB	98	80
		WB	98	
		WBG	98	

The ratings given the other panels, which had then been exposed for 10 years and 9 months, are shown in the accompanying Table I which has been prepared for this purpose and also to show the spreading rate of the paint on each panel and having new tabulation showing a so-called "duration of good preservation," the basis of which is explained by a note at the foot of the tabulation.

This table presents the important characteristics and results of the tests to date in a compact form. It shows the relative thickness of the coatings, which should be inversely proportional to the spreading rate, and certain marked relations between this characteristic and the duration of preservation will be observed. The "duration of good preservation" is a necessarily approximate determination but perhaps will serve as a comparative measure of the results.

Photographs of reprepared panels Nos. 1, 2, 3 and 10 and original panels Nos. 4, 6 and 16 were taken on November 29, 1927, through Mr. McDonnell's agency and are reproduced in Figs. 1 to 7. These figures will perhaps assist in gaging the sub-committee's ratings.

TABLE I.—RESULTS OF TESTS TO DETERMINE THE EFFECT OF VARIOUS METHODS OF PREPARATION OF STEEL SURFACES ON THE PRESERVATION OF SUCH SURFACES BY PAINT.

Panel	Surface Condition and Preparation	Recorded Spreading Rate, sq. ft. per gallon			Latest Rating of Altoona Panels, per cent		Duration of Good Preservation[c]			
							Altoona		Brooklyn	
		First Coat	Second Coat	Average per coat	Nov., 1927	Oct., 1925	Year of Rating	Elapsed Years	Year of Rating	Elapsed Years
	NEW STEEL PANELS									
No. 1	Clean surface, mill scale intact, no surface cleaning or treatment, painted in warm dry room	888	944	916	[h]	10	1922	5	1921	4
No. 2	Mill scale broken, some rust and grease, handcleaned with benzine, scraper and wire brush, painted in warm dry room	701	951	826	[h]	25	1923[d]	6	1919	2
No. 3	Sandblasted, painted immediately after in warm dry room	663	906	785	[h]	80	1926[e]	9	1919	2
No. 4	Sandblasted, heated in oven to 225° F., then painted	854	944	899	10	35	1924	7	1919	2
No. 5	Sandblasted, placed in cool damp room 40 minutes, then painted	619	793	706	70	84	1926[e]	9	1919	2
No. 6	Sandblasted, placed out doors and painted there at a temperature of 25 to 27° F	518	567	542	80	84	1927	$10\frac{3}{4}$	1922	5
No. 7	Sandblasted, exposed out of doors for 7 days, painted over rust in warm dry room	617	1211	914	45	55	1924	8+	1920	3
No. 8	Pickled, neutralized, washed with hot water, painted in warm dry room	709	906	807	80	84	1927	$10\frac{3}{4}$	1919	2
No. 9	Pickled, neutralized, washed with hot water, exposed out of doors 7 days, painted over rust in warm dry room	666	1387	1028	40	50	1924	7	1919	2
No. 10	Exposed to weather 6 mos., cleaned with wire brush and scraper	503	799	653	10	15	1918	1	1918	1
No. 10(a)	Former Brooklyn panel No. 10, reprepared by sandblasting one-half surface, hand-cleaning the other half of same, painted June 13, 1921	[g]	[g]	[g]	95[a] 60[b]	95[a] 70[b]	1927 1924	$6\frac{1}{2}$[f] 3	....	.. ..
No. 11	Pickled, washed with cold water under pressure, painted in warm dry room	748	854	801	80	88	1927	$10\frac{3}{4}$	1918	1
No. 16	Incompletely sandblasted, painted in warm dry room	736	900	818	10	45	1923[d]	6	1921	4
	OLD STEEL PANELS									
No. 12	Cleaned with wire brush only	514	744	629	75	82	1926[e]	9	1919	2
No. 13	Cleaned with benzine, scraper and wire brush	612	841	726	60	68	1924	7	1919	2
No. 14	Benzine applied over rust spots and burned off with torch, then cleaned with scraper and wire brush	625	835	730	65	80	1925	8	1922	5
No. 15	Sandblasted	670	864	767	50	73	1924	7	1919	2

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[a] Sandblasted section. [b] Wire brushed section.

[c] This is here considered to be the last inspection at which the panel was rated 80 per cent or higher.

[d] No inspections between November 24, 1922, and February 27, 1924. Rating was above 80 per cent at former and below at latter date.

[e] No inspections between February 27, 1925, and November 10, 1927. Rating was above 80 per cent at former and below at latter date.

[f] Rated 95 per cent on November 10, 1927. [g] Not recorded. [h] Original discontinued.

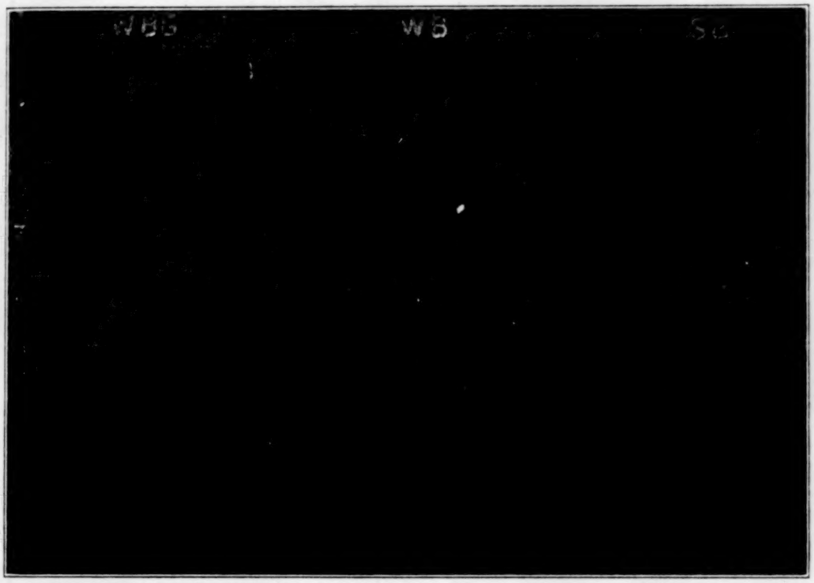

FIG. 1.—Panel No. 1, After 2 Years Exposure as Re-prepared
Rating.—Inspection November 10, 1927: *SB* 98 per cent; *WB* 85 per cent; *WBG* 90 per cent.

FIG. 2.—Panel No. 2, After 2 Years Exposure as Re-prepared.
Rating.—Inspection November 10, 1927: *SB* 98 per cent; *WB* 95 per cent; *WBG* 95 per cent.

FIG. 3.—Panel No. 3, After 2 Years Exposure as Re-prepared.

Rating.—Inspection November 10, 1927: *SB* 98 per cent; *WB* 98 per cent; *WBG* 98 per cent.

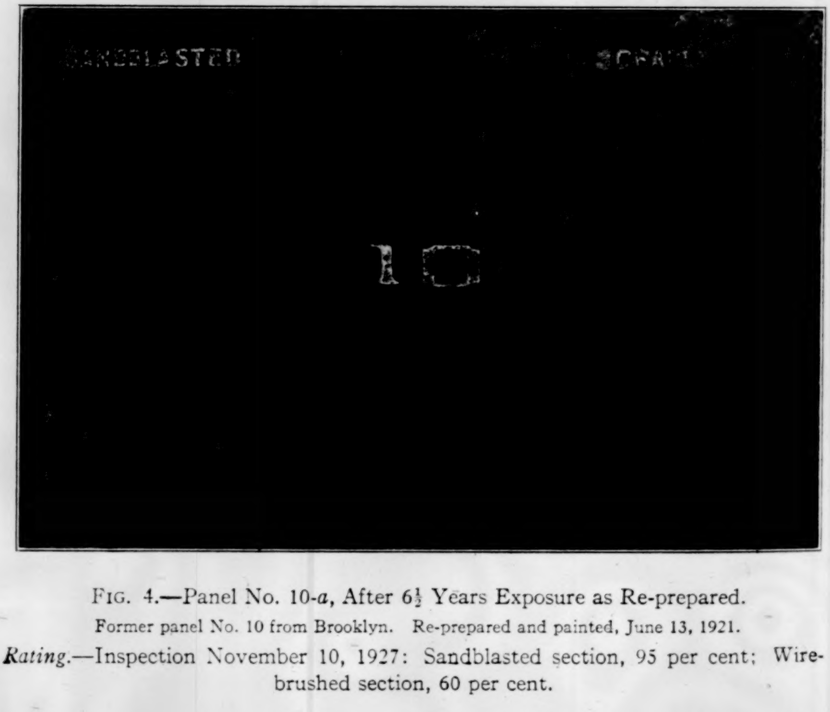

FIG. 4.—Panel No. 10-*a*, After 6½ Years Exposure as Re-prepared.

Former panel No. 10 from Brooklyn. Re-prepared and painted, June 13, 1921.

Rating.—Inspection November 10, 1927: Sandblasted section, 95 per cent; Wire-brushed section, 60 per cent.

FIG. 5.—Panel No. 4, After 10 Years, 9 Months Exposure.
Rating.—Inspection November 10, 1927: 10 per cent.

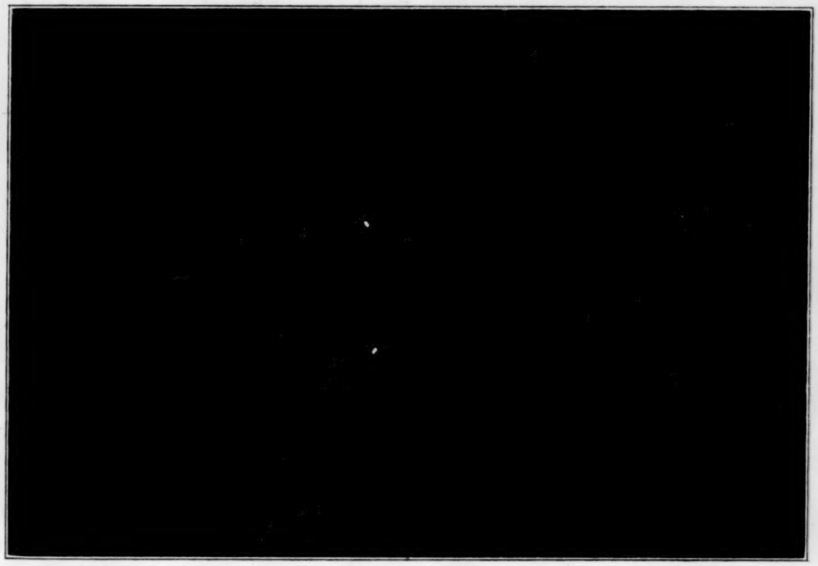

FIG. 6.—Panel No. 6, After 10 Years, 9 Months Exposure.
Rating.—Inspection November 10, 1927: 80 per cent.

FIG. 7.—Panel No. 16, After 10 Years, 9 Months Exposure.
Rating.—Inspection November 10, 1927: 10 per cent.

REPORT OF SUB-COMMITTEE XV ON SPECIFICATIONS FOR PIGMENTS DRY AND IN OIL WHEN MARKETED IN THAT FORM

During the year various comments have been received on details of the present tentative specifications for pigments. These have been considered by the sub-committee and some of them have led to proposals for revision.

Members of Sub-Committee XXV on Cellulose Ester Coatings have cooperated in a discussion of the very simple requirements for sampling included in the present specifications. It has been stated that for high-grade pigments such as are used in lacquers, samples from a much larger percentage of the packages are necessary. It is the sense of Sub-Committee XV that it would not be practical to include in general specifications for pigments requirements to satisfy all consuming interests, therefore all the tentative specifications should be revised by omitting all reference to sampling.

Sub-Committee XXV also asks for consideration of requirements for oil absorption and for more detailed requirements for determination of mass color. The sub-committee plans to give consideration to these details as soon as Sub-Committee VIII on Methods of Analysis of Paint Materials completes its work on preparing methods for making these tests.

The following revisions are recommended in the individual specifications:

Tentative Specifications for Aluminum Powder for Paints (D 266 - 27 T).[1]—In order to provide a more appropriate title to these specifications and to recognize the distinction between what is frequently called aluminum bronze powder for paints (although it contains no alloy of the class known as bronze), and aluminum powder used for other purposes, it is recommended that the title be changed to read as follows by the addition of the italicized words:

Aluminum Powder for Paints (*Aluminum Bronze Powder*)

Section 2.—Improved methods of analysis have shown that there is more lubricant in aluminum powder than at first supposed. It is therefore recommended that Paragraph (*b*) of Section 2 be revised by changing the maximum requirement for fatty matter from 3 per cent to 4 per cent.

It has been found that the requirement for leafing properties is not adapted to some aluminum powders. Therefore it is recommended that Paragraphs (*c*) and (*d*) of Section 2 be changed from their present form: namely,

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 860 (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 329.

> (*c*) It shall have good "leafing" properties (by "leafing" is understood the property of forming an apparently continuous brilliant film over the entire free surface of a mixture of the powder in spar varnish within one minute after cessation of stirring the mixture).
>
> (*d*) A residue of not more than 0.2 per cent shall be retained on a No. 100 sieve when the powder is washed through with alcohol. It shall "leaf" readily with spar varnish[a] and when mixed with such varnish in the proportion of 2 lb. to the gallon shall give a free flowing, smooth, continuous coating.
>
> [a] Federal Specifications Board Specification No. 186, Varnish, Spar, Water-Resisting.

to read as follows:

> (*c*) A residue of not more than 0.2 per cent shall be retained on a No. 100 sieve, using alcohol as the wash liquid.
>
> (*d*) The powder shall have good "leafing" properties. (By "leafing" is understood the property of forming an apparently continuous brilliant film over the entire free surface of a mixture of the powder in a suitable liquid, within one minute after cessation of stirring the mixture.) For this test the powder shall be mixed in the proportion of 2 lb. to a gallon of the liquid. As thus mixed it shall also give a free flowing, smooth, continuous coating.
>
> NOTE.—A suitable liquid is made by mixing spar varnish conforming to Federal Specifications Board Specification No. 18b with turpentine conforming to the Standard Specifications for Gum Spirits of Turpentine and Steam-Distilled Wood Turpentine (Serial Designation: D 13) of the American Society for Testing Materials in such proportions that the mixture will have a viscosity of 0.65 to 0.85 poises (*B* to *C* of the Gardner-Holt scale).

Tentative Specifications for Gold Bronze Powder (*D 267 - 27 T*).[1]—*Section 2.*—As alloys other than copper-zinc alloys are sometimes used, the sub-committee recommends that the first sentence of Paragraph (*b*) of Section 2 be revised by the omission of the words in brackets:

> It shall be made from new ingot metals [and the finished powder shall consist essentially of copper and zinc].

Experience with the leafing test has been somewhat the same as in the case of aluminum powder. The sub-committee therefore recommends that Paragraphs (*c*) and (*d*) of Section 2 be changed from their present form: namely,

> (*c*) It shall "leaf" readily with spar varnish and ordinary bronzing liquids, and when mixed in the proportion of 3½ to 4 lb. to a gallon, shall give a free flowing, smooth, continuous coating.
>
> (*d*) A residue of not more than 0.1 per cent shall be retained on a No. 100 sieve.

to read as follows:

> (*c*) A residue of not more than 0.2 per cent shall be retained on a No. 100 sieve, using alcohol as the wash liquid.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 861 (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 330.

(*d*) The powder shall have good "leafing" properties. (By "leafing" is understood the property of forming an apparently continuous brilliant film over the entire free surface of a mixture of the powder in a suitable liquid, within one minute after cessation of stirring the mixture.) For this test the powder shall be mixed in the proportion of 3 to 4 lb. to a gallon of the liquid. As thus mixed it shall also give a free flowing, smooth, continuous coating.

NOTE.—A suitable liquid is made by mixing spar varnish conforming to Federal Specifications Board Specification No. 18b with turpentine conforming to the Standard Specifications for Gum Spirits of Turpentine and Steam-Distilled Wood Turpentine (Serial Designation: D 13) of the American Society for Testing Materials in such proportions that the mixture will have a viscosity of 0.65 to 0.85 poises (*B* to *C* of the Gardner-Holt scale).

Tentative Specifications for Prussian Blue (D 261 - 27 T).[1]—

Section 3.—It has been found that the determination of coarse particles in the dry pigment is very unsatisfactory. Concordant and reliable results are not obtained. In view of these conditions as well as the very infrequent occurrence of appreciable amounts of coarse particles it is recommended that the requirement for coarse particles in dry pigment appearing in Paragraph (*b*) of Section 3, be omitted. This requirement reads as follows:

Coarse particles (total residue retained on a No. 325 screen), maximum per cent...... 1.0.

Tentative Specifications for Commercial Para Red (D 264 - 27 T).[1]—

Section 2.—It is found that considerable quantities of para red are now made with a base of calcium carbonate instead of barium sulfate and that the calcium carbonate has certain advantages for some purposes. It is therefore recommended that Paragraph (*a*) of Section 2 be changed to read as follows by the addition of the italicized words:

2. (*a*) *Dry Pigment.*—The pigment shall be para nitraniline red toner, *which, unless otherwise specified by the purchaser, shall be* precipitated on a white base consisting of barium sulfate with or without siliceous materials.

The sub-committee recommends that upon revision as indicated above and in addition the omission of the requirement covering sampling in each specification, the following tentative specifications be advanced to standard:

Tentative Specifications for Prussian Blue (D 261 - 27 T);[1]
Tentative Specifications for Ultramarine Blue (D 262 - 27 T);[1]
Tentative Specifications for Chrome Oxide Green (D 263 -27 T);[1]
Tentative Specifications for Commercial Para Red (D 264 - 27 T);[1]

The Tentative Specifications for Aluminum Powder for Paints (D 266 - 27 T) and the Tentative Specifications for Gold Bronze

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, pp. 850–857 (1927); also 1927 Book of A.S.T.M. Tentative Standards, pp. 319–326.

Powder (D 267 – 27 T), revised as recommended above, are recommended to be continued as tentative. It is expected to continue the study of these specifications during the year.

The sub-committee wishes to correct an error appearing in the Standard Specifications for Red Lead (D 83–24).[1] In Section 3 (*b*) of these specifications the quantity of raw linseed oil for red lead paste should be changed from 4½ pts. to 3 pts.

Respectfully submitted on behalf of the sub-committee,

H. E. SMITH,
Chairman.

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 251.

REPORT OF SUB-COMMITTEE XXII ON METHOD OF APPLICATION OF PAINT BY SPRAYING

In the report of the sub-committee for 1922[1] a description was given of the tests which the committee had recently initiated on the comparison of hand-brushing *versus* spraying. In these tests four frame dwelling houses at Bridgeville, Pa., were painted October 11 and 13, 1921, two houses being sprayed and two houses being brushed. The data in respect to these tests are given in the report of the sub-committee for 1922.

The houses were inspected on October 3, 1924, and the condition of the paint was given in the report of the sub-committee for 1925.[2]

On October 8, 1927, a further inspection was made as to the condition of the paint on these houses and while three full years have elapsed since the former inspection, making the paints now six years old, there is relatively no change in the rating of any of the paints since the last report.

Briefly, the inspection immediately after painting, the inspection after three years weathering, and the present inspection after six years weathing all rate the houses in the same order. The house on which the most paint was used, namely, No. 3, made the best showing in all inspections.

The object of the test was not only to obtain data as to cost per square foot for material and labor and the comparative speed of hand brushing *versus* spraying, but also to discover if the same paint applied under the same conditions by brush and spray would be equally as durable. This test clearly indicates that paint which was sprayed did not fail any more rapidly than the paint which was brushed. All of the paints after six years were chalking rather freely, but not so very much more than they were three years ago.

The sub-committee is still looking for a suitable location where some very large buildings can be sprayed, some of which will be brushed for another thorough test to show the exact comparison between brushing and spraying on large surfaces.

Respectfully submitted on behalf of the sub-committee.

R. E. Rogers,
Chairman.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 384 (1922).

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 25, Part I, p. 243 (1925).

REPORT OF COMMITTEE D-2

ON

PETROLEUM PRODUCTS AND LUBRICANTS

Committee D-2 on Petroleum Products and Lubricants has held three regular meetings during the past year (in June at French Lick Springs, Ind., in January at Baltimore, and in March at Cleveland) and also, the usual informal meeting in December at Chicago, at the time of the annual meeting of the American Petroleum Institute.

Three new sub-committees have been formed this year, as follows:

XXIX on Motor Oils;
XXX on Fuel Oils, and
Special Sub-Committee to cooperate with the Committee on Revision of the Pharmacopœia of the U. S. A. in developing methods of testing petrolatum and petrolatum liquidum.

Sub-Committee XXVII on Application of Tests (C. A. Lunn, chairman), composed of the chairmen of all regular sub-committees, was appointed in 1925 to prepare a statement covering the applicability of tests used for petroleum products and the significance of the results obtained. This statement has been completed and appears in separate pamphlet form, entitled, "The Significance of Tests of Petroleum Products."

The voting membership of this committee now consists of 40 producer, 30 consumer and 11 general interest members.

NEW TENTATIVE METHODS

The committee is presenting for approval for publication as tentative, the following methods:

1. *Tentative Definitions of Terms Relating to Petroleum*, submitted by Sub-Committee XX on Nomenclature and appended hereto.[1]

2. *Tentative Method of Test for Distillation of Crude Petroleum*, submitted by Sub-Committee XXI on Crude Petroleum and appended hereto.[2]

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[1] See p. 933.—ED.

[2] See p. 917.—ED.

3. *Tentative Method of Test for the Determination of Autogenous Ignition Temperatures*, submitted by Sub-Committee XXVIII on Autogenous Ignition of Petroleum Products and appended hereto.[1]

4. *Tentative Method of Test for Gravity of Petroleum and Petroleum Products by Means of the Hydrometer*, submitted by the special Sub-Committee on Specific Gravity (K. G. Mackenzie, chairman) and appended hereto.[2]

RECOMMENDED REVISION OF TENTATIVE METHOD

The committee recommends a slight change in the following method of test and, upon approval of this revision, that the method be continued as tentative.

Tentative Method of Test for Melting Point of Petrolatum (D 127 - 24 T).[3]—

A slight revision is recommended by Sub-Committee I on Petrolatum as follows:

Section 5 (a).—After the sentence "The material shall be melted slowly in a casserole or other suitable dish with stirring until the temperature reaches 180° F.," insert a new sentence to read "A fresh portion of the sample shall be used for each determination."

EDITORIAL REVISION OF TENTATIVE METHOD OF TEST

Tentative Method of Test for Penetration of Grease and Petrolatum (D 217 - 27 T).[4]—The following clarification in the use of the terms "penetration" and "consistency" is recommended as an editorial correction of the method of test:

Section 3.—Change the first sentence to read as follows by the addition of the italicized words and the omission of those in brackets:

> *The consistency shall be determined by measuring* the penetration [shall be measured] on what is customarily known as an asphalt penetrometer such as that described in the *Proceedings* of the American Society for Testing Materials, Vol. VII, p. 626 (1907), and illustrated in Fig. 3 herein.

Section 13.—In the second and fifth lines, change the word "consistency" to "penetration."

ADVANCEMENT OF TENTATIVE METHODS TO STANDARD

The committee recommends the submission of the following tentative methods to letter ballot of the Society for adoption as standard:

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[1] See p. 915.—ED.

[2] See p. 924.—ED.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 24, Part I, p. 872 (1924); also 1927 Book of A.S.T.M. Tentative Standards, p. 416.

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 930 (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 421.

1. *Test for Saponification Number (D 94 – 21 T)*,[1] slightly modified and brought into conformity with the rules of the Society for Standard Methods, in accordance with recommendations of Sub-Committee XIII on Neutralization Number and Saponification (H. T. Kennedy, chairman) as follows:

Insert at the head of this method a new section on Scope to read as follows:

Scope.—This method is one of the means used for the identification of unmixed animal and vegetable oils, and for measuring the quantity of fatty material in compounded products. It may also be used in the study of non-compounded petroleum products.

Apparatus.—After "Erlenmeyer flask" in the first sentence, insert "of chemically resistant glass."

At the end of the method. add two new paragraphs to read as follows:

The above calculations and data presume a knowledge of the nature of the fat present. In an unknown sample, and particularly when a low saponification number leaves doubt as to whether fat is actually present, the fatty acid may be extracted (as the soap) and recovered for gravimetric determination. For this purpose, the saponified and neutralized solution, obtained as above, shall be handled as in a grease analysis, following the second paragraph of Section 19 of the Standard Method of Analysis of Grease (Serial Designation: D 128) of the American Society for Testing Materials.[2] The fatty acid is thus obtained and may then be used for subsequent identification tests.

ACCURACY

It may be expected that the same operator will find variations of ± 0.3 saponification number on compounded oils containing less than 30 per cent compounding; ± 0.5 saponification number on compounded oils containing over 30 per cent compounding; and ± 1.0 saponification number for unmixed fatty oils. Corresponding permissible variations for different operators will be ± 0.5, ± 1.0 and ± 2.0 saponification numbers, respectively. For dark oils, the errors may be double this magnitude.

The figures given were arrived at after a study of data reported by Committee D-1 in 1911 on saponification numbers of 16 samples of linseed oil by seven observers, and check data on 26 samples of compounded oils and 2 samples of sperm oils.

2. *Test for Cloud and Pour Points of Petroleum Products (D 97 – 27 T)*,[3] slightly modified in accordance with the recommendations of Sub-Committee XVI on Cloud and Pour Test as follows:

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 21, p. 663 (1921); also 1927 Book of A.S.T.M. Tentative Standards, p. 430.

[2] 1927 Book of A.S.T.M. Standards, Part II, p. 355.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 919 (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 390.

Section 8.—Change the word "requirements" in the last line of this section to read "specifications."

Section 9.—In the note to this section, add the word "crystals" to the end of the phrase "For temperatures down to −15° F., crushed ice and calcium chloride."

Section 11.—After the first sentence, insert a sentence to read as follows:

> The jar may be marked to indicate the proper level.

3. *Methods of Testing Gas Oils* (*Gravity, Distillation, Sulfur, Carbon Residue, Pour Point, Viscosity, Water*) (*D 158 - 25 T*)[1] subject to the advancement to standard of the Tentative Method of Test for CarbonResidue of Petroleum Products (D 189 - 27 T) and the Tentative Method of Test for Cloud and Pour Points of Petroleum Products (D 97 - 27 T).

4. *Test for Carbon Residue of Petroleum Products* (*Conradson Carbon Residue*) (*D 189 - 27 T*),[2] slightly modified in accordance with the recommendations of Sub-Committee XXIII on Carbon Residue, as follows:

Section 2.—Change Paragraph (*b*) to read as follows by the addition of the italicized words and the omission of those in brackets:

> Skidmore iron crucible *flanged and ringed*, 60 to 80-ml. approximate capacity, *55 mm.* (*$2\frac{1}{8}$ in.*) *inside, and* 65 mm. ($2\frac{5}{8}$ in.) [in] outside diameter at the top 37 to 39 mm. (about $1\frac{1}{2}$ to $1\frac{5}{8}$ in.) in height, supplied with a cover without delivery tubes and having the vertical opening closed. The horizontal opening shall be kept clean.

Change Paragraph (*d*) to read as follows by the addition of the italicized words and the omission of those in brackets:

> [Bare nichrome wire triangle] *Triangle of bare nichrome wire of approximately No. 13 B. & S. gage* having an opening small enough to support the bottom of the sheet-iron crucible at the same level as the bottom of the asbestos block or hollow sheet-metal box, Paragraph (*f*).

Change Paragraph (*e*) to read as follows by the addition of the italicized words and the omission of those in brackets:

> Circular sheet-iron hood from 120 to 130 mm. ($4\frac{3}{4}$ to $5\frac{1}{4}$ in.) in diameter, the height of the *lower* perpendicular side to be from 50 to 53 mm. (2 to $2\frac{1}{8}$ in.); provided at the top with a chimney 50 to 60 mm. (2 to $2\frac{1}{2}$ in.) in height and from 50 to 56 mm. (2 to $2\frac{1}{4}$ in.) inside diameter, which is attached to the lower part having the perpendicular sides by a cone-shaped member, bringing the total height of the complete hood from 125 to 130 mm. ($5\frac{1}{8}$ in.). *The hood may be made from a single piece of metal provided the foregoing dimensions are adhered to.* As a guide for the height of the flame above the chimney, a bridge [of] *made of approximately 3-mm.* (*$\frac{1}{8}$-in.*) *iron or nichrome* wire, *h*, shall be attached having a height of 50 mm. (2 in.) above the top of the chimney.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 25, Part I, p. 732 (1925); also 1927 Book of A.S.T.M. Tentative Standards, p. 411.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 915 (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 386.

Section 3.—In the second paragraph of this section, insert the words "or ring" after the phrase "On a suitable stand."

PROPOSED REVISIONS OF STANDARD METHODS

The committee recommends the following revisions of standard methods to become effective immediately. It accordingly asks for the necessary nine-tenths vote:

1. *Test for Steam Emulsion of Lubricating Oils* (*D 157 - 27*).[1]—For the sake of clarification, the following revisions are recommended, as submitted by Sub-Committee XI on Turbine Oils (J. T-B. Bowles, chairman):

Section 1.—Add a footnote to the section to read as follows:

> Methods for sampling are covered in the Tentative Methods of Sampling Petroleum and Petroleum Products (Serial Designation: D 270 - 27 T) of the American Society for Testing Materials. The following paragraphs, which are particularly important for protection of samples for the steam emulsion test, are quoted from these methods:
>
> "34. (*a*) Corks for bottles shall be clean, free from holes and loose bits of cork.
>
> "(*b*) Sealing wax, or paraffin, shall *not* be poured over corks after cooling."

Section 4.—Change to read as follows by the omission of the words in brackets:

> The baths shall be [either] of [metal or] glass with a capacity of 3 to 3½ liters and a depth of 7½ to 9 in. A good quality battery jar or beaker is entirely satisfactory. [A glass bath shall be used for emulsification and a metal or glass bath may be used for the separation.]

Section 9.—Change the note to this section to read as follows by the addition of the italicized words and the omission of those in brackets:

> NOTE.—Care must be taken if glass battery jars are used, as direct heating by flame or electric [hot point] *heater* may cause breakage. [Use of steam in this connection insures against breakage.]

Section 11.—Beginning with the sixth sentence, change to read as follows by the addition of the italicized words and the omission of those in brackets:

> The contents of the oil container shall be examined at least every 30 seconds, and the volume of the separated oil layer shall be recorded. *When this reading operation has continued until 20 cc. of oil have separated, the elapsed time in seconds shall be reported as the Steam Emulsion Number* (*S. E. No.*). *No differentiation shall be made between clear and turbid oil.* This examination shall be made

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 414.

> *without* [by] withdrawing the oil container and its contents from the separating bath and reading the volumes.
>
> [NOTE.—This operation shall not require over five seconds. No differentiation shall be made between clear and turbid oil.]
>
> [This reading operation shall be continued until 20 cc. of oil have separated. In cases where the 20-cc. oil layer does not separate in 20 minutes, the test shall be discontinued at this point.]
>
> In cases where the interface between more-or-less clear oil and the emulsion is not a clear, straight horizontal line, the position of such a line [is] *should be* carefully estimated to the nearest 0.5 cc.
>
> *If 20 cc. of oil do not separate, the test shall be discontinued.*

Section 12.—Omit the second and third sentences of this section, reading as follows:

> In order to establish a basis for comparison, a definite value of 60 shall be assigned to an oil, which under conditions of the tests separates completely from emulsion in one minute. This is equivalent to an emulsion separation rate of 0.33 cc. per second or 20 cc. per minute.

Section 13.—Change the first sentence of this section to read as follows by the addition of the italicized words and the omission of those in brackets:

> Results shall be reported, to the nearest second, of the time necessary for [complete (20 cc.)] *20 cc.* oil separation.

2. *Test for Water in Petroleum Products and Other Bituminous Materials (D 95 – 27).*[1]—The following revisions are recommended in the method, as submitted by Sub-Committee XIV on Water and Sediment (H. R. Gundlach, chairman) in order that a satisfactory joint between the condenser and trap may be made:

Section 5.—Change the first sentence to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

> The condenser shall be of the water-cooled, reflux, glass-tube type, having a condenser jacket not less than 400 mm. (15¾ in.) in length with an inner tube [12 to 16 mm. (½ to ⅝ in.)] *9.5 to 12.7 mm. (⅜ to ½ in.)* in *outside* diameter.

3. *Test for Water and Sediment in Petroleum Products by Means of Centrifuge (D 96 – 24).*[2]—The following revisions are recommended, as submitted by Sub-Committee XIV on Water and Sediment (H. R. Gundlach, chairman) in order that the description may apply to forms of tube shown in the figure accompanying the method:

Section 4.—Change the third sentence of this section to read as follows by the addition of the italicized words and the omission of those in brackets:

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 433.

[2] *Ibid.*, p. 437.

The graduations shall be clear and distinct, reading upward from the bottom of the tube [as follows:]. *The value of the divisions for each range shall not be greater than shown in the following tabulation:*

Appended hereto are reports of the following sub-committees:

Sub-Committee I on Petrolatum
Sub-Committee III on Paraffin Wax
Sub-Committee IX on Precipitation
Sub-Committee X on Oxidation at High Temperatures
Sub-Committee XV on Sampling and Gaging
Sub-Committee XVI on Cloud and Pour Points
Sub-Committee XVIII on Gas Oil
Sub-Committee XX on Nomenclature
Sub-Committee XXI on Crude Petroleum
Sub-Committee XXIII on Carbon Residue
Sub-Committee XXVIII on Autogenous Ignition of Petroleum Products
Sub-Committee XXX on Fuel Oil.

The committee has re-elected the present officers to serve for the ensuing term of two years.

The recommendations appearing in this report have been submitted to letter ballot of the committee, which consists of 81 members; 49 ballots have been returned and 32 members have refrained from voting. The result of the letter ballot is as follows:

Item	Affirmative	Negative	Not Voting
I. PROPOSED NEW TENTATIVE METHODS			
Tentative Definitions of Terms Relating to Petroleum	48	1	0
Tentative Method of Test for Distillation of Crude Petroleum	45	1	3
Tentative Method of Test for the Determination of Autogenous Ignition Temperatures	39	3	7
Tentative Method of Test for Gravity of Petroleum and Petroleum Products	48	0	1
II. REVISION OF TENTATIVE METHOD			
Tentative Method of Test for Melting Point of Petrolatum (D 127 - 24 T)	48	0	1
III. ADVANCEMENT OF TENTATIVE METHODS TO STANDARD			
Test for Saponification Number (D 94 - 21 T)	49	0	0
Test for Cloud and Pour Points of Petroleum Products (D 97 - 27 T)	43	4	2
Testing Gas Oils (Gravity, Distillation, Sulfur, Carbon Residue, Pour Point, Viscosity, Water) (D 158 - 25 T)	44	1	4
Test for Carbon Residue of Petroleum Products (Conradson Carbon Residue) (D 189 - 27 T)	49	0	0
IV. REVISIONS OF STANDARD METHODS			
Test for Steam Emulsion of Lubricating Oils (D 157 - 27)	47	0	2
Test for Water in Petroleum Products and Other Bituminous Materials (D 95 - 27)	48	0	1
Test for Water and Sediment in Petroleum Products by Means of Centrifuge (D 96 - 24)	49	0	0

This report has been submitted to letter ballot of the committee, which consists of 81 members; 49 members returned their ballots, of whom 49 have voted affirmatively, 0 negatively, and 0 have marked their ballots "not voting."

Respectfully submitted on behalf of the committee,

F. A. HULL,
Chairman.

R. P. ANDERSON,
Secretary.

EDITORIAL NOTE

The Tentative Methods of Test for Saponification Number; Test for Cloud and Pour Points of Petroleum Products; and Test for Carbon Residue of Petroleum Products (Conradson Carbon Residue) as revised by the committee were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on September 1, 1928, and appear in the 1928 Supplement to Book of A.S.T.M. Standards. The Tentative Methods of Testing Gas Oils were approved at the annual meeting as recommended by the committee and subsequently adopted by letter ballot of the Society on September 1, 1928, and appear in the 1928 Supplement to Book of A.S.T.M. Standards.

The proposed revisions of the Standard Methods of Test for Steam Emulsion of Lubricating Oils; Test for Water in Petroleum Products and Other Bituminous Materials; and Test for Water and Sediment in Petroleum Products by Means of Centrifuge were approved at the annual meeting by a nine-tenths vote and were subsequently adopted by letter ballot of the Society on September 1, 1928. The methods in their revised form appear in the 1928 Supplement to Book of A.S.T.M. Standards.

The proposed revision of the Tentative Method of Test for Melting Point of Petrolatum was accepted. The method as revised appears on page 931.

The proposed Tentative Definitions of Terms Relating to Petroleum; Methods of Test for Distillation of Crude Petroleum; Test for the Determination of Autogenous Ignition Temperatures; and Test for Gravity of Petroleum and Petroleum Products, were accepted for publication as tentative and appear on pages 933, 917, 915 and 924, respectively.

REPORT OF SUB-COMMITTEE I ON PETROLATUM

The investigation on melting point of petrolatum reported upon last year[1] has been continued. The melting points of six samples of petrolatum have been determined by six laboratories by four different methods as follows: The A.S.T.M. method carried out in accordance with the Tentative Method of Test for Melting Point of Petrolatum (D 127 – 24 T),[2] the plate method described in the report of the committee for 1921,[3] the U. S. Pharmacopœia method,[4] and the Ubbelohde method.[5]

The results of these tests are given in Table I.

It may be seen that so far as concordance is concerned, there is little to choose between the A.S.T.M. and plate methods, and this is in confirmation of the results obtained last year. The other two methods appear to be distinctly less reliable. This is also shown in the following table, which indicates that more difficulty is experienced with samples of low than of high melting point:

Difference Between Maximum and Minimum Values, deg. Fahr.

Method	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4	Sample No. 5	Sample No. 6
A.S.T.M.	5	7	4	6	1	3
Plate	5	7	3	5	2	3
U. S. Pharmacopœia[a]	11	15	12	6	2	7
Ubbelohde[a]	9	12	7	3	4	4

[a] Five laboratories only.

Table II shows again the greater concordance obtained with samples Nos. 5 and 6 having a high melting point. The average melting points, as obtained by the different methods, are given in Table III.

In the opinion of the sub-committee, because of the much greater concordance shown by the other two methods, no further consideration need be given to the Pharmacopœia and Ubbelohde methods. While the plate method appears to be slightly more concordant and much more expeditious than the A.S.T.M. method, especially when several checks are desired, it is believed that these advantages are

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 448 (1927).

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 24, Part I, p. 872 (1924); also 1927 Book of A.S.T.M. Tentative Standards, p. 416.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 21, p. 357 (1921).

[4] Holde, "Examination of Hydrocarbon Oils," Mueller's translation, 1915, p. 189.

[5] *Zeitschrift für Angewandte Chemie*, 18 (1905), pp. 1220–1225.

TABLE I.—RESULTS OF TESTS ON MELTING POINT OF PETROLATUM, DEG. FAHR.

LABORATORY	SAMPLE No. A-1	SAMPLE No. A-2	SAMPLE No. D-1	SAMPLE No. D-2	SAMPLE No. V-1	SAMPLE No. V-2
A.S.T.M. METHOD						
No. 1	118	126	122	111	126	145
No. 2	117	125	121	110	125	142
No. 3	120	129	123	113	126	145
No. 4	118	127	122	110	126	143
No. 5	115	122	121	109	125	142
No. 6	115	123	119	107	125	142
Average Deviation from Mean, per cent	1.37	1.60	0.82	1.21	0.40	0.86
PLATE METHOD						
No. 1	112	121	118	106	125	142
No. 2	116	125	120	108	126	144
No. 3	114	122	119	107	126	142
No. 4	112	122	119	107	125	143
No. 5	111	118	117	103	124	141
No. 6	114	123	118	106	126	142
Average Deviation from Mean, per cent	1.34	1.51	0.63	1.10	0.53	0.54
U. S. PHARMACOPŒIA METHOD						
No. 1	111	120	117	102	125	141
No. 2	102	105	109	100	123	135
No. 3	112	120	117	102	125	142
No. 4	...	...	...	...	...	...
No. 5	108	122	121	102	125	142
No. 6	113	118	116	106	125	141
Average Deviation from Mean, per cent	2.93	4.10	2.41	1.21	0.51	1.48
UBBELOHDE METHOD						
No. 1	102	110	113	100	122	140
No. 2	106	112	112	100	123	136
No. 3	...	...	...	...	...	...
No. 4	111	122	120	102	124	140
No. 5	106	113	116	103	126	140
No. 6	104	114	114	102	125	138
Average Deviation from Mean, per cent	2.12	2.73	2.09	1.10	0.97	1.04

MEAN DEVIATIONS OF ALL LABORATORIES:

A.S.T.M. Method	1.04 per cent
Plate Method	0.94 "
U. S. Pharmacopœia Method	2.02 "
Ubbelohde Method	1.68 "

outweighed by the greater simplicity of the apparatus required for the A.S.T.M. method. This should facilitate the general adoption of the latter method, especially in small laboratories.

TABLE II.—EXCESS IN VALUES FOR MELTING POINT AS OBTAINED WITH A.S.T.M. METHOD AS COMPARED WITH VALUE OBTAINED BY PLATE METHOD, DEG. FAHR.

LABORATORY	SAMPLE No. 1	SAMPLE No. 2	SAMPLE No. 3	SAMPLE No. 4	SAMPLE No. 5	SAMPLE No. 6
No. 1	6	5	4	5	1	3
No. 2	1	0	1	2	−1	−2
No. 3	6	7	4	6	0	3
No. 4	6	5	3	3	1	0
No. 5	4	4	4	6	1	1
No. 6	1	0	1	1	−1	0
Average excess	2.5 °F.					

TABLE III.—AVERAGE MELTING POINT, FOR SIX SAMPLES OF PETROLATUM, DEG. FAHR.

LABORATORY	A.S.T.M. METHOD	PLATE METHOD	U. S. PHARMACOPŒIA METHOD	UBBELOHDE METHOD
No. 1	124.7	120.7	119.5	114.5
No. 2	123.3	123.2	112.3	114.8
No. 3	126.0	121.7	120.0	.....
No. 4	124.3	121.3	.....	119.8
No. 5	122.3	119.0	120.0	117.3
No. 6	121.8	121.5	120.0	116.2
Average	123.7	121.2	118.3	116.5

As it has been found that with some samples of petrolatum there is a change of melting point due to remelting, it is recommended that the Tentative Method D 127 – 24 T be modified as follows:

Section 5 (a).—After the second sentence add a new sentence reading as follows:

> A fresh portion of the sample shall be used for each determination.

Respectfully submitted on behalf of the sub-committee,

WINSLOW H. HERSCHEL,
Chairman.

REPORT OF SUB-COMMITTEE III ON PARAFFIN WAX

The work of the sub-committee during the past year has consisted of a further study of various methods of determining oil in wax in the chairman's laboratory, the results of which appear in the appendix to the report, and a series of cooperative tests on samples containing various amounts of oil.

It has been found that for waxes containing more than 4 per cent of oil, both the solvent index of refraction and the solidification point methods give low results due to incomplete extraction of oil. Accordingly, the procedures have been modified to provide a second extraction in both methods. It has also been found that the solvent index of refraction method and the direct refraction method give results which are of the order of 35 per cent too low on waxes containing oil from Pennsylvania crude oil.

Five samples, ranging in oil content from 0.5 per cent to 10.3 per cent, were tested by five laboratories cooperating in this work. The waxes were tested for oil by four methods:

(*a*) Solvent index of refraction method (modified as described in the Appendix);

(*b*) Solidification point method (modified as described in the Appendix);

(*c*) Direct refraction method (*Industrial and Engineering Chemistry*, Vol. 19, pp. 125–127);

(*d*) Press method (Day's Handbook of the Petroleum Industry, Vol. 1, pp. 724–726).

While the results secured in the chairman's laboratory were in reasonable agreement with the amounts of oil actually in the samples in the case of the solvent index of refraction, the direct refraction, and the solidification point methods, the agreement between the other laboratories with all methods was so poor that it was thought undesirable to include the results in the present report. The reason for this lack of agreement is thought to be due either to lack of familiarity with the methods or to changes in the oil content of the samples before testing. Since the indications are that if a substitute for the press method is to be obtained it will have to be selected from the group of methods under consideration, additional samples will be sent out for further cooperative testing work.

Respectfully submitted on behalf of the sub-committee,

J. B. Rather,
Chairman.

APPENDIX

DETERMINATION OF OIL IN WAX

The work herein described was conducted in the laboratory of the chairman of the sub-committee, J. B. Rather, for the purpose of determining whether, when considerable amounts of oil are present, extraction is complete when the procedures for the solvent index and solidification point methods published in an earlier report of the committee[1] are followed, and for the purpose of determining the influence of the source of oil on the results obtained by the solvent index of refraction method.

During the investigation of the solvent index and the solidification point methods, it soon became apparent that the directions for these methods, as originally outlined, did not adequately provide for the complete removal of the oil from wax samples containing percentages of oil in excess of 4 per cent. To this end the following changes in these methods were suggested to the members of Sub-Committee III participating in the cooperative testing:

In the solvent index of refraction method, the volume of the filtrate and washings from the ethylene dichloride extraction shall be increased from 150 to 250 cc. In the case of samples containing 4 per cent or more of oil, a second extraction with ethylene dichloride shall be made. The filtrate and washings from the second extraction shall be combined with those from the first extraction, and the oil in these combined extracts determined in the manner described.

In the solidification point method, the sample shall be reduced from 10 to 5 g. The volume of the filtrate and washings from the ethylene dichloride extraction shall be increased from 200 to 250 cc. In the case of samples containing 4 per cent or more oil, a second extraction with ethylene dichloride shall be made. The filtrate and washings from this second extraction shall be combined with those from the first extraction and the oil in these combined extracts determined in the manner described. The second extraction, mentioned above, is always followed by a third extraction in order to secure oil-free wax suitable for the construction of the calibration curve, as outlined in the method.

On the evaporation of the extract containing the wax for the construction of the calibration curve, the presence of any yellow color is an indication that the removal of oil by the previous extraction has been incomplete.

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[1] See *Proceedings*, Am. Soc. Testing Mats., Vol. 25, Part I, p. 263 (1925); Vol. 27, Part I, p. 450 (1927).

The following table shows how the oil apportions itself in the case of the two consecutive extractions:

Total Oil in Sample, per cent	Method of Test	First Extraction, per cent	Second Extraction, per cent	Total
5.3	Solidification Point	3.22	2.31	5.53
10.3	Solvent Index	8.50	1.67	10.17
10.3	Solvent Index	8.33	1.56	9.89
10.3	Solidification Point	8.89	1.08	9.97
5.0 Pennsylvania 34 distillate	Solidification Point	3.75	1.07	4.82
5.0 Pennsylvania 34 distillate	Solidification Point	3.49	1.31	4.80
5.0 Pennsylvania 34 distillate	Solvent Index	4.76	1.00	5.76
5.0 Pennsylvania 34 distillate	Solvent Index	5.23	0.98	6.21
5.0 Pennsylvania 34 distillate	Solvent Index	4.63	0.66	5.29

These results indicate the evident need for a second extraction in the case of those waxes which contain oil in excess of 4 per cent.

Both the solvent index of refraction method and the direct refractometric method are dependent on the assumption that the refractive index of the oil in the wax has a known value. In the case of the solvent index of refraction method this value for Mid-Continent distillate is said to lie between 1.4856 and 1.4914 at 77° F., and in the case of the direct refractometric method, 1.4780 at 140° F. is assumed as the refractive index of the oil in the wax. Since the refractive index of the oil in any wax is an inherent property of the hydrocarbons of which such oil is composed, it is obvious that the index will vary with the nature of the paraffin cut and with the source of the crude oil. To show how different the refractive indices at 77° F. and 140° F. of samples of pressed distillate from various sources can be, the following results are given:

Nature of Distillate	Refractive Index at 77° F.	Refractive Index at 140° F.
Manufacturer A. . Pressed distillate from Mid-Continent crude oil	1.4890	1.4780
Manufacturer B. . Pressed distillate from Pennsylvania crude oil	1.4740	1.4625
Manufacturer B. . Pressed distillate from mixture of Pennsylvania and Ranger crude oils	1.4832	1.4718
Manufacturer C. . Pressed distillate from Pennsylvania crude oil	1.4763	1.4652

It is obvious from these figures that for the accurate determination of the oil in any sample of wax it is necessary to know the refractive index of the oil itself. In the case of samples of wax from unknown sources this would necessitate the extraction of a portion of this oil and a determination of its index of refraction. The figures given below show the error which would be made if a sample of wax containing oil from Pennsylvania crude oil were analyzed by either the solvent index or the direct refractometric method, and the index of refraction for Mid-Continent distillate were used in calculating the results, instead of the index for Pennsylvania distillate:

	Percentage of oil which would be shown on analysis if the refractive index of Mid-Continent distillate were used in calculating the results instead of the refractive index of Pennsylvania distillate.	
PERCENTAGE OF OIL, REFRACTIVE INDEX AT 77° F., 1.4740; AT 140° F., 1.4625	SOLVENT INDEX OF REFRACTION METHOD	DIRECT REFRACTION METHOD
2.00	1.30	1.20
5.00	3.20	3.00
10.00	6.50	6.20
20.00	13.00	12.40

From these figures we see that, in the case of a wax containing 5 per cent of oil from Pennsylvania distillate, the results of analysis of such a wax by the solvent index or the direct refractometric method would show only about 3 per cent of oil if the refractive index for Mid-Continent distillate were used in calculating the results. In an actual test with a wax to which had been added 5.0 per cent of oil from Pennsylvania distillate the solvent index of refraction method showed only 3.1 per cent of oil. The solidification point method, which is free from any assumptions relative to the nature of the oil in the wax, showed an oil content for this sample of 4.81 per cent.

In the solidification point method the only assumption involved is that the wax, obtained in the final extraction and used in the construction of the calibration curve, has the same effect on the solidification point as the wax obtained in the other extractions. In order to investigate the validity of this assumption 100 g. of 108 to 110° F. melting point wax was extracted with ethylene dichloride until free of oil. These extracts were subjected to a series of recrystallizations until the wax component was obtained oil free. The main body of the wax, also oil free, was subjected to a final extraction with ethylene dichloride in order to secure a sample of wax analogous to that used in the construction of the calibration curve. This last mentioned wax, when compared with that obtained by recrystallization from the first extracts, had, as shown below, an identical effect on the raising of the solidification points:

Solid point of 865 oil	15° F.
Solid point of 865 oil plus 2 per cent of recrystallized wax	25° F.
Solid point of 865 oil plus 2 per cent of wax from final crystallization	25° F.

These results indicate that the assumption that these two waxes have identical effects on the two solidification points is justified.

Some idea of the time required for an operator to analyze a sample of wax for oil by the refractometric methods and the solidification point procedure is indicated below:

METHOD	TIME REQUIRED TO MAKE A SINGLE ANALYSIS
Direct Refractometric	1 hour
Solvent Index of Refraction	4 hours
Solidification Point	8 hours

It is obvious, of course, that the amount of time required to complete several analyses, by any one method, would not be much greater than that required to make a single analysis by that method.

The results of the experiments with the above methods lead to the following conclusions:

1. The solidification point method is freer from assumptions than any of the other methods and for wax samples of unknown origin can be relied upon to give correct results in the hands of an operator familiar with the method.

2. The solvent index of refraction method is somewhat shorter than the solidification method but has the disadvantage that it is necessary to know the origin of the sample or the refractive index of the oil which it contains. Frequently information as to the source of the wax is not available, or the sample is inadequate for the determination of the refractive index of the oil component.

3. The direct refractometric method is open to the same objections as the solvent index of refraction method with the added disadvantage that an error of 0.0002 in the determination of the index of refraction is equivalent to about 0.5 per cent of oil. It is obvious that this method is unsuitable for the determination of small percentages of oil in wax. However, the rapidity of this method especially recommends it as a plant control method, where great accuracy is not desired and where the origin of the product is known.

REPORT OF SUB-COMMITTEE IX ON PRECIPITATION

Since the latter part of 1924, the main efforts of this committee have been confined to the standardization of naphtha to be used in the Tentative Method of Test for Precipitation Number of Lubricating Oils (D 91 – 21 T).[1] Naphtha standardization is important, not only from the standpoint of the precipitation number test, but also from the standpoint of a large number of other tests in which asphaltic material is precipitated from oil by the addition of a solvent.

Due to the broad interest in this subject, therefore, this report contains a brief history of the standardization of naphtha, a review of the previous work of the committee, and a specification for a naphtha which can fairly readily be made by most refiners and which appears to give satisfactory results.

The proposed specifications submitted at the meeting of Committee D-2 on March 26, 1928, and the proposed modifications suggested at that meeting for future work, are as follows:

	Specifications Submitted (based on previous work)	Specifications (proposed for future work)
Gravity, deg. A. P. I	70–73	70–73
Aniline Point, deg. Cent	58–60	58–60
Distillation Test (A.S.T.M. Method D 86):		
Initial Boiling Point, deg. Fahr	113–131	not less than 122
50-per-cent Point, deg. Fahr		158–176
End Point, deg. Fahr	not more than 248	not more than 266

The precipitation numbers obtained with the revised specification naphtha will be compared with the data at hand to determine definitely whether such a naphtha will give comparable and reproducible results.

Previous Work on Development of Satisfactory Solvent

In 1923, W. C. Marckworth, then chairman of the sub-committee, submitted a report showing that the gravimetric method as well as the A.S.T.M. method yielded widely varying results with naphthas of the same gravity. Accordingly he recommended that further work be concentrated on standardization of the diluent rather than on the details of the methods. In 1924, W. E. Perdew in a communication to P. A. Crosby, then chairman, pointed out that E. A. Evans had concluded from his experiments that the difference between the tar solubility in naphthas of the same gravity and distillation range was due to the presence of aromatics. Mr. Crosby, in discussing the results obtained up to 1924, stressed the importance of including more rigid boiling range requirements for the naphtha specifications.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 21, p. 648 (1921); also 1927 Book of A.S.T.M. Tentative Standards, p. 427.

The number of diluents which have been under investigation both here and abroad for the purpose of developing a suitable solvent for the determination of asphaltic constituents in petroleum products, can be divided into two groups, (1) organic solvents of a definite chemical composition and (2) light petroleum distillates of various boiling ranges. Briefly, solvents under the first group were found unsuitable for precipitation work for various reasons; solvents under the second group were investigated under Mr. Crosby's chairmanship resulting in a recommendation submitted in 1925 for a solvent of the following specifications:

Initial Boiling Point	150–160° F.
End Point	195–205° F.
Aniline Point	not less than 64° C.

Within recent years the solution in aniline of various petroleum products, particularly light naphthas, has come to be regarded as a means of separating various aromatics and naphthenic constituents as well as a means of determining their presence. G. Chavanne and L. J. Simon have found during the analysis of a typical gasoline which consisted in the determination of aromatic and saturated cyclic hydrocarbons, that two relations may be obtained from which the amounts of each constituent may be calculated by measuring the critical temperature of solution of the original sample in aniline, and by measuring the critical temperature of solution of the sample freed from the aromatic hydrocarbons by treatment with H_2SO_4-HNO_3 mixture. Their method consisted of observing the maximum temperature at which turbidity appeared when varying amounts of aniline were taken with a given amount of the sample.

Tizard and Marshall, in their investigation of petroleum naphthas, have found the critical temperature of solution method tedious and impractical, so they determined the solution temperature of equal volumes of the sample and aniline, that is, the temperature at which two liquid layers are formed upon cooling the solution from higher temperatures. This temperature is called the aniline point.

The aniline point method used by the committee may be briefly outlined as follows: Ten cubic centimeters of the sample and ten cubic centimeters of the aniline (freshly distilled, free from aminothiophenes) are measured into a large test tube fitted with a stirrer and thermometer. The mixture is heated until it becomes homogeneous, and then is allowed to cool until it becomes turbid. The temperature is then raised slightly and a duplicate determination made. A slight initial turbidity is disregarded, the temperature being taken when the solution becomes completely cloudy. The means of heating is a naked flame. If the aniline point is more than 10° C. above the room temperature, another larger tube is used to form an air jacket. Tizard and Marshall have found that in a mixture of naphtha containing from 5 to 40 per cent of aromatics, there is a differential temperature gradient varying from 4.2 to 5.8° C. for each 5 per cent increment.

RECENT EXPERIMENTAL DATA

The early part of the investigation in the chairman's laboratory was an attempt to prepare naphtha comparable to Mr. Crosby's specification naphthas from four different samples of crude oil and by chemical treatment to bring the aniline point up to 64° C. Only in the case of Pennsylvania crude oil has there been any success in securing aniline points approaching in value the specification of not less than 64° C., despite the fact that particular precautions were taken by sulfonation followed by nitration to remove in so far as possible all unsaturated and aromatic compounds. Even with certain samples of Pennsylvania crude oil, the apparent presence of a certain quantity of naphthene hydrocarbons which are not affected by sulfonation and nitration prevents the obtaining of a sufficiently high aniline point.

In this connection, it became necessary to investigate the suitability of using a pure hydrocarbon such as normal heptane as a standard of reference and to prepare, from Pennsylvania and Mid-Continent crude oils, a solvent which would give the same precipitation numbers as would normal heptane. For this purpose narrow-cut naphthas were prepared from these two crude oils and the precipitation numbers obtainable with these narrow-cut naphthas were compared with those obtainable from normal heptane on three samples of oils, the one being a steam-refined Mid-Continent cylinder stock, and the other two being Mid-Continent black oils of varying characteristics as indicated below:

	GRAVITY, A.P.I. AT 60° F.	FLASH POINT, DEG. FAHR.	FIRE POINT, DEG. FAHR.	POUR POINT, DEG. FAHR.	SAYBOLT UNIVERSAL VISCOSITY AT 210° F.
Oil No. 1..........	19.0	520	600	30/60	160
Oil No. 2..........	21.1	425	495	50/55	127
Oil No. 3..........	16.8	470	560	50/55	225

TABLE I.—COMPARATIVE DATA ON ANILINE POINTS AND PRECIPITATION NUMBERS.

		Aniline Point,	Precipitation Numbers		
	Naphthas	Deg. Cent.	Oil No. 1	Oil No. 2	Oil No. 3
No. 1	Atlantic Refining Co. A.S.T.M. Naphtha	58.4	0.15 0.15	1.05 1.10	2.90 3.00
No. 2	Standard Oil Co. (Indiana) A.S.T.M. Naphtha	56.6	0.06 0.05	0.80 0.85	2.25 2.30
No. 2(*a*)	Standard Oil Co. (Indiana) A.S.T.M. Naphtha, treated with 10 per cent by volume of fuming H_2SO_4	58.0	....	1.10	2.80
No. 3	Kahlbaum's Holde Benzine	59.4	0.17 0.15	1.00 1.15	2.75 3.00
No. 4	Tidewater Oil Co. Current A.S.T.M. Naphtha	62.0	0.15 0.25	1.20 1.25	3.50 3.50
No. 5	Holde Precipitation Naphtha from California Crude Oil	51.7	0.04	0.70	1.80
No. 6	Sun Oil Co. Oxidation Naphtha	58.8	0.10	1.20	2.90
No. 7	A.S.T.M. Naphtha from Pennsylvania Crude Oil	61.1	0.30	1.50	3.60
No. 8	A.S.T.M. Naphtha from Mid-Continent Crude Oil	59.8	0.20 0.20	1.20 1.15	3.00 3.00
No. 9	A.S.T.M. Naphtha from blend of Lago and California Crude Oils	53.3	0.20	0.85	2.00
No. 10	70-per-cent A.S.T.M. Naphtha from Pennsylvania Crude Oil and 30-per-cent A.S.T.M. Naphtha from Lago and California Crude Oils	59.0	0.20	1.15	3.00
No. 11	20-per-cent Standard Oil Co. (Indiana) A.S.T.M. Naphtha and 80-per-cent A.S.T.M. Naphtha from Pennsylvania Crude Oil	60.9	....	1.40	....
No. 12	40-per-cent Standard Oil Co. (Indiana) A.S.T.M. Naphtha and 60-per-cent A.S.T.M. Naphtha from Pennsylvania Crude Oil	58.2	0.12	1.10	3.00

TABLE II.—PRECIPITATION NUMBERS USING NAPHTHAS OF 58 TO 60° C. ANILINE POINT RANGE.

Naphtha	Aniline Point, deg. Cent.	Precipitation Numbers		
		Oil No. 1	Oil No. 2	Oil No. 3
No. 1	58.4	0.15	1.08	2.95
No. 2 (Acid Treated)	58.0	....	1.10	2.80
No. 3	59.4	0.16	1.13	2.88
No. 6	58.8	0.10	1.20	2.90
No. 8	59.8	0.20	1.18	3.00
No. 10	59.0	0.20	1.15	3.00
No. 12	58.2	0.12	1.10	3.00

From the results obtained, it would seem that there will be some difficulty in obtaining a solvent which will produce the same results as does normal heptane on all types of material tested, and that it will

TABLE III.—DISTILLATION DATA OF THE EXPERIMENTAL NAPHTHAS, A.S.T.M. METHOD D 86-27.

Naphtha	Gravity, 60° F., degrees A. P. I.	Distillation Temperature, deg. Fahr.						
		Initial Boiling Point	10-per-cent Point	20-per-cent Point	50-per-cent Point	70-per-cent Point	90-per-cent Point	End Point
No. 1	71.1	136	153	155	166	178	201	291
No. 2	68.4	135	158	165	181	194	212	275
No. 3	71.2	158	160	162	165	170	181	241
No. 4	72.1	133	147	156	171	187	216	271
No. 5	64.7	153	163	165	171	176	185	244
No. 6	72.2	131	149	153	160	169	185	241
No. 7	73.8	127	149	151	160	167	181	244
No. 8	72.3	131	154	156	162	169	183	244
No. 9	66.3	122	154	160	180	190	210	264
No. 10	72.3	131	151	154	167	176	194	262
No. 11	73.2	133	149	153	163	172	189	257
No. 12	70.9	133	151	156	167	178	196	255

TABLE IV.—DATA ON ANILINE POINT AND PRECIPITATION VALUES OF SOME TREATED AND UNTREATED NAPHTHAS.

Naphtha	Aniline Point, deg. Cent.	Precipitation Numbers		
		Oil No. 1	Oil No. 2	Oil No. 3
Standard Oil Co. (Indiana) A.S.T.M. Naphtha	56.6	0.05	0.83	2.25
Standard Oil Co. (Indiana) A.S.T.M. Naphtha treated with 10 per cent by volume of fuming H_2SO_4	58.0	....	1.10	2.80
Holde Precipitation Naphtha from California Crude Oil	51.7	0.04	0.70	1.80
Holde Precipitation Naphtha from California Crude Oil, treated with 10 per cent by volume of fuming H_2SO_4	51.9	....	0.80	....
Holde Precipitation Naphtha from California Crude Oil, treated with 50 per cent by volume of fuming H_2SO_4	51.9	....	0.75	....

TABLE IV.—DATA ON ANILINE POINT AND PRECIPITATION VALUES OF SOME TREATED AND UNTREATED NAPHTHAS. (*Continued*)

NAPHTHA	ANILINE POINT, DEG. CENT.	PRECIPITATION NUMBERS OIL NO. 1	OIL NO. 2	OIL NO. 3
A.S.T.M. Naphtha from blend of Lago and California Crude Oils............	53.3	0.02	0.85	2.00
A.S.T.M. Naphtha from blend of Lago and California Crude Oils, treated with aniline at 100° F..............	55.0	....	0.90	....

evidently be necessary to calibrate each batch of naphtha in terms of normal heptane on a whole series of oils of varying properties in order to obtain results at all reproducible by various laboratories.

Consequently, efforts were confined to standardizing naphthas from crude oil by very stringent specifications, particularly in view of the fact that standardization by the use of aniline point specification somewhat lower than that recommended by Crosby seemed to offer some promise.

Experimental Work Since Committee D-2 Meeting, January, 1928:

The present experimental work has been performed for the purpose of ascertaining the following points:

1. Will a stringent specification of boiling point and aniline point give duplicable results with naphthas from various sources?
2. Is it possible to choose an aniline point range in naphtha which will permit various refineries to prepare satisfactory naphtha for precipitation tests?
3. Can a naphtha of a lower aniline point be increased to a higher aniline point by treatment or blending and be satisfactory?
4. Is it necessary to modify the present A.S.T.M. distillation range for precipitation naphtha?

Tables I to IV give data on twelve samples of naphtha, showing, Table I, Comparative Data on Aniline Points and Precipitation Numbers; Table II, Precipitation Numbers Using Naphthas of 58 to 60° C. Aniline Point Range; Table III, Distillation Data of the Experimental Naphthas; Table IV, Data on Aniline Point and Precipitation Values of Some Treated and Untreated Naphthas.

CONCLUSIONS

1. It is to be noted that all naphthas which have an aniline point between 58 and 60° C. give satisfactory precipitation values despite the fact that they have been obtained from different sources of crude oil and prepared in different refineries.

2. It is further to be noted that it is possible to blend a high aniline point naphtha with a low aniline point naphtha and obtain one with an aniline point which will give precipitation numbers similar to the other naphthas of the same aniline point range.

3. The end points of the naphthas were not carefully controlled and it will be seen that these vary from 241 to 291° F., and yet the agreement in precipitation value is satisfactory so long as the aniline point is within the limits outlined. This merely indicates that the boiling point range is not a major factor in precipitation naphtha specifications.

4. Naphtha No. 6 is the naphtha used by Sub-Committee X on Oxidation at High Temperatures in its recent work with the Sligh Oxidation test and this fact furnishes an excellent opportunity for correlating the work of the two committees.

RECOMMENDATIONS

The suggested requirements for a solvent based on recent experimental work and the modified boiling range of the solvent as suggested at the meeting of Committee D-2 on March 26, 1928, are as follows:

	SPECIFICATIONS SUBMITTED (BASED ON PREVIOUS WORK)	SPECIFICATIONS (PROPOSED FOR FUTURE WORK)
Gravity, deg A. P. I.	70–73	70–73
Aniline Point, deg. Cent.	58–60	58–60
Distillation Test (A.S.T.M. Method D 86):		
Initial Boiling Point, deg. Fahr.	113–131	not less than 122
50-per-cent Point, deg. Fahr.	....	158–176
End Point, deg. Fahr.	not more than 248	not more than 266

Samples of naphtha complying with the proposed changes in the boiling range will be investigated for the purpose of ascertaining definitely whether such naphthas will give comparable and reproducible results.

Respectfully submitted on behalf of the sub-committee,

L. W. PARSONS,
Chairman.

REPORT OF SUB-COMMITTEE X ON OXIDATION AT HIGH TEMPERATURES

During the past year, cooperative tests were carried out with the Sligh oxidation equipment, following the procedure described in the 1927 report of the committee.[1] Two series of tests were made, the results of the first series being reported to the Society last June. The second series of tests, which was not quite so extensive, also shows that reasonably good check results are obtainable.

At the meeting of Committee D-2 January, 1928, it was agreed:

1. That given a standard naphtha or other solvent, a little further work on the details of procedure would probably render the Sligh test as reproducible as any other form of high-temperature oxidation test is likely to be.

2. That Sub-Committee X would cooperate with other sub-committees in obtaining a suitable standard naphtha.

3. That the sub-committee would cooperate with other sub-committees, particularly Sub-Committee XI on Turbine Oils, in the endeavor to establish the interpretation of high-temperature oxidation tests.

The supposed function of a high-temperature oxidation test is to produce in an oil, as rapidly as possible, changes of the same kind as would normally take place during long periods of actual service. It appears probable that the nature of an oxidation test would have to bear some definite relationship to the type of service for which the oils were intended. For instance, it is very doubtful if an oxidation test run under conditions which would give results of use in the evaluation of turbine oils would also be applicable to insulating oils. While tests of a similar nature might be suitable for both classes of oil, the exact procedure would also certainly have to be varied, since the decomposition products which are most undesirable in the one case are not the same as those which are most undesirable in the other case. It therefore appears that the utmost caution should be observed in considering the possible standardization of a high-temperature oxidation test.

It is the opinion of some members of the sub-committee that, with reference to turbine oils, the Sligh test is of value, but it is considered by many other members that the experimental evidence is at present far too meager for any general acceptance of the value of such a test. It is hoped that cooperation with the Sub-Committee on Turbine Oils will clarify the situation, although owing to the very slow deterioration of turbine oils in service it is not expected that any conclusions will be reached for some considerable time to come.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 461 (1927).

Most of the other oxidation tests suggested have been of much longer duration. One of these tests is being used quite extensively by Mr. T. H. Rogers, and a few members of the sub-committee will conduct this test to see whether any relation can be established between it and the Sligh test. Similarly, tests will be made using the Funk sludge accelerating machine with a similar object in view.

In conclusion, the sub-committee feels that concentration upon the turbine oil problem is at present the most promising field.

Respectfully submitted on behalf of the sub-committee,

A. LUDLOW CLAYDEN,
Chairman.

REPORT OF SUB-COMMITTEE XV ON SAMPLING AND GAGING

The Tentative Methods of Sampling Petroleum and Petroleum Products (D 270 - 27 T) substantially as adopted by the Society in 1927 have appeared in *Technical Paper No. 323B* of the Bureau of Mines, with the U. S. Government Master Specifications for Lubricants and Liquid Fuels and Methods for Sampling and Testing, Federal Specifications Board, Specification No. *2d* as revised October 21, 1927. The International Electrotechnical Commission at the meeting held during the summer of 1927 in Italy accepted the A.S.T.M. method for sampling insulating oils with only some minor changes to adapt it to European practice.

No recommendations for changes in the Tentative Methods of Sampling have been received, but it may be expected that the wide distribution now being given by publication in the Society's publications and by the U. S. Government in *Technical Paper 323B*, and the promulgation by the International Electrotechnical Commission will bring out suggestions in the next year or two. Pending the receipt and consideration of such suggestions, no recommendations for further changes should be made.

The sub-committee is giving consideration to formulating methods for gaging. Particular consideration is being given to the following:

1. Weighing methods.
2. Temperature determinations:
    - (*a*) Temperature distribution;
    - (*b*) Temperature averages.
3. Expansion tables and coefficients.
4. Strapping and other methods for calculating volume.
5. Flow measurements for volume determination.

It appeared from discussion in the sub-committee that *Circular No. 154* of the U. S. Bureau of Standards has not covered the full range needed by users. The sub-committee therefore adopted a resolution as follows:

> RESOLVED: That Sub-Committee XV on Sampling and Gaging recommend, through Committee D-2 on Petroleum Products and Lubricants and the Society, that the Bureau of Standards be asked:
>
> 1. To extend Tables 4 and 5 of U. S. Bureau of Standards *Circular No. 154* to cover the range from 10 to 0° A.P.I.
> 2. To extend Tables 1, 2 and 3 to cover the same addition to the A.P.I. scale without, however, using negative values unless it is felt to be absolutely necessary.
> 3. That the temperature range of Tables 1, 2 and 3 be extended to parallel that of the abridged table in the supplement to *Circular No. 154*.

Respectfully submitted on behalf of the sub-committee,

A. E. FLOWERS,
Chairman.

REPORT OF SUB-COMMITTEE XVI ON CLOUD AND POUR TEST

The sub-committee recommends that the Tentative Method of Test for Cloud and Pour Points of Petroleum Products (D 97 - 27 T)[1] be advanced to standard.

During the year, Sub-Committee XVI has cooperated with the American Leather Chemists Association in helping them to develop a cold test for neatsfoot oil. At the request of this association, and with the approval of the Society, a joint committee was appointed with R. R. Matthews as chairman, the personnel consisting of the members of Sub-Committee XVI and eight members of the American Leather Chemists Association. Samples of neatsfoot oil have been sent to all members of the joint committee for comparative tests of cloud and pour point using Tentative Method D 97 - 27 T.

Respectfully submitted on behalf of the sub-committee,

R. R. Matthews,
Chairman.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 919 (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 390.

REPORT OF SUB-COMMITTEE XVIII ON GAS OIL

Sub-Committee XVIII recommends that the Tentative Methods of Testing Gas Oils (D 158 – 25 T)[1] be advanced to standard, subject to advancement to standard of the following tentative methods of test, which are specified in the gas oil Methods of Testing Gas Oils:

Tentative Method of Test for Carbon Residue in Petroleum Products (D 189 – 27 T);

Tentative Method of Test for Cloud and Pour Points of Petroleum Products (D 97 – 27 T).

During the year, members of the sub-committee representing a cooperating committee of the American Gas Association asked that consideration be given to a method of distillation in which the apparatus specified conforms substantially with that described in A.S.T.M. Tentative Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment (Serial Designation: D 20 – 26 T)[2] as a possible substitute for the present tentative distillation method. Comparative tests of the proposed and present tentative distillation methods were made by the individual members of the committee. The results reported showed that the two methods gave very similar distillation data for gas oils, but a number of criticisms of the proposed method were offered. A majority of the sub-committee members stressed the point that the present tentative distillation method is now widely established in industry and that it would be inadvisable to substitute another method unless it was shown to possess outstanding advantages. A ballot of the sub-committee, consisting of 7 members, on the question as to whether the proposed distillation method should be substituted for the present tentative distillation method resulted in 5 negative votes, one affirmative vote and one member not heard from at the time of this report.

No criticism of the other methods of test specified in the Methods of Testing Gas Oils has been received.

Respectfully submitted on behalf of the sub-committee,

CHARLES A. LUNN,
Chairman.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 25, Part I, p. 732 (1925); also 1927 Book of A.S.T.M. Tentative Standards, p. 411.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, p. 881 (1926); also 1927 Book of A.S.T.M. Tentative Standards, p. 505.

REPORT OF SUB-COMMITTEE XX ON NOMENCLATURE

In the report of Committee D-2 presented to the Society in 1923[1] there were published for information definitions for the terms crude petroleum, weathered crude, benzine, petroleum naphtha, gasoline and petroleum spirits.

These definitions were revised and again printed for information in the report of the committee presented to the Society in 1924[2] with additional definitions for kerosine, mineral seal oil, gas oil, fuel oil, tar, pitch, grease, oil-shale, shale oil, and end point.

In the report of Committee D-2 to the Society in 1925[3] the definitions were again printed for information including new definitions for engine distillate and tops.

These definitions have been further revised slightly by the sub-committee as a result of criticisms and suggestions and are now recommended for publication as tentative.[4]

Respectfully submitted on behalf of the sub-committee,

K. G. MACKENZIE,
Chairman.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 390 (1923).

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 24, Part I, p. 563 (1924).

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 25, Part I, p. 287 (1925).

[4] See p. 933.—ED.

REPORT OF SUB-COMMITTEE XXI ON CRUDE PETROLEUM

For reports of previous work of the sub-committee see the report of Committee D-2 in the Proceedings of the American Society for Testing Materials, Vol. 24, Part I, p. 566 (1924) and Vol. 25, Part I, p. 290 (1925).

This report presents tabulated results of work done on the naphtha content of three crude oils; light California crude oil, average Mid-Continent pipe-line oil as received at an Atlantic Coast refinery, and light Caddo (Louisiana) crude oil. The apparatus used was a modification of the U. S. Bureau of Mines Hempel apparatus as described in Bureau of Mines *Bulletin No. 207.*[1] Instead of the condenser used by the Bureau of Mines, the naphtha condenser of the A.S.T.M. Standard Method of Test for Distillation of Gasoline, Naphtha, Kerosine, and Similar Petroleum Products (D 86 - 27)[2] was used. The apparatus and procedure is described in detail in the proposed methods for distillation of crude petroleum being recommended by Sub-Committee XXI for publication as tentative.[3]

The apparatus described in the proposed tentative method was decided upon with the idea of providing a simple apparatus made up of equipment readily available in the average petroleum laboratory, and which would be preferable to the gravity determination as a basis for evaluation of refinable crude petroleum. The results of the work on the three crude oils are given in Table I. It will be noted that satisfactory checks are obtained for the percentages of naphtha in the crude oils and that the results of the naphtha distillation are in close agreement.

The principal objections to the method that have been raised are the following: (1) the apparatus does not provide enough fractionation; (2) the charge is so small that for many crude oils more than one run is necessary to obtain enough naphtha for the subsequent A.S.T.M. naphtha distillation; (3) the glass flask is a fire hazard with oils containing more than about 1 per cent of water; and (4) the method is not flexible enough in that it does not provide a means of determining the kerosine content of crude oils, which is sometimes a factor in the price paid for the crude oil.

The answers offered to these objections are as follows: (1) The method yields at least as much naphtha as the average good refinery

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[1] E. W. Dean and others, "The Analytical Distillation of Petroleum and Its Products," U. S. Bureau of Mines *Bulletin No. 207*, 1922.

[2] 1927 Book of A.S.T.M. Standards, Part II, p. 378.

[3] See p. 917.—Ed.

TABLE I.—RESULTS OF TESTS FOR NAPHTHA CONTENT OF CRUDE OILS, EMPLOYING THE MODIFIED HEMPEL STILL, RUNNING TO 392° F.

Laboratory	Gravity of Crude, deg. A. P. I.	Per Cent off at 392° F.	Gravity of Cut, deg. A. P. I.	Initial Boiling Point of Cut, deg. Fahr.	Distillation Temperature, deg. Fahr											Distillation Values, per cent			
					10 per cent	20 per cent	30 per cent	40 per cent	50 per cent	60 per cent	70 per cent	80 per cent	90 per cent	95 per cent	End Point	212° F.	221° F.	284° F.	392° F.
									LIGHT CALIFORNIA CRUDE OIL										
No. 1	26.5	23.7 24.0	53.0 53.1	132	200	225	242	257	272	288	306	326	352	381	410	14.6	18.2	57.7	96.4
		24.0 24.0	53.0 53.1	132	200	225	242	257	272	288	307	327	354	382	410	14.2	18.0	57.7	96.8
No. 2	26.5	23.3 23.2	[a]	124	198	224	241	258	272	288	300	326	351	373	406	15.0	19.0	58.0	97.5
		23.2 23.1	[a]	128	201	225	241	255	271	286	304	323	350	368	406	14.0	18.5	58.5	98.0
		23.3 23.1	[a]	125	200	225	240	256	272	285	302	325	350	370	404	14.0	19.0	58.5	98.0
No. 3	26.6	23.33	52.7	129	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	408	13.5	17.0	55.5	96.5
No. 4	26.4	22.5 22.5	53.4	144	206	227	240	253	267	284	303	324	352	...	412	13.0	17.0	60.0	97.0
No. 5	26.5	23.67 23.8 24.0 23.8	53.6 53.6 53.6 53.6	138	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	410	13.0	17.0	60.0	97.0
No. 6	26.6	24.0 24.0	52.9	111	195	220	237	253	269	289	307	331	360	...	409	16.5	21.0	57.0	95.5
No. 7	26.5	23.6	....	140	203	226	243	258	273	289	306	326	356	380	...	13.0	17.0	56.5	....
No. 8	26.5	23.78 23.74	....	130	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	351	...	402	13.5	19.0	58.0	97.5
		23.74 23.78	....	133	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	354	...	400	13.5	18.5	58.5	97.0
No. 9	26.7	22.42	53.4	127	201	225	241	257	271	289	307	329	356	385	410	14.0	18.5	57.5	96.0

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[a] Did not report.

[b] Did not report 10-per-cent temperatures.

TABLE I.—*Continued*

Laboratory	Gravity of Crude, deg. A. P. I.	Per Cent off at 392° F	Gravity of Cut, deg. A. P. I.	Initial Boiling Point of Cut, deg. Fahr	Distillation Temperature, deg. Fahr.											Distillation Values, per cent			
					10 per cent	20 per cent	30 per cent	40 per cent	50 per cent	60 per cent	70 per cent	80 per cent	90 per cent	95 per cent	End Point	212° F.	221° F.	284° F.	392° F.
MID-CONTINENT PIPE LINE OIL																			
No. 1	35.8	30.0 30.3	59.2 59.2	110	174	210	230	247	266	283	305	326	354	382	406	21.8	26.0	60.2	96.2
		30.6 30.3	59.3 59.3	110	175	208	230	248	266	285	306	326	357	385	408	21.5	26.0	59.9	96.0
No. 2	35.7	30.1 30.0	[a]	110	175	208	229	248	268	287	305	325	352	373	405	22.0	26.0	58.5	97.0
		30.0 30.0	[a]	109	178	209	230	250	267	286	306	321	356	384	411	21.5	25.5	59.0	96.5
		30.2 30.0	[a]	110	176	208	232	251	270	288	307	322	354	380	406	21.5	26.0	59.0	97.0
No. 3	36.0	31.0	58.6	113	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	410	21.5	25.0	57.5	95.5
No. 4	35.7	28.8 28.5	58.7	118	184	211	231	248	265	283	303	327	356	...	417	20.5	25.0	60.5	96.5
No. 5	35.7	30.67 31.0 30.5	58.6 58.6 58.6	111	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	412	21.0	25.0	58.0	96.0
No. 6	35.9	30.5 30.5	58.7	98	174	206	228	248	269	288	310	333	363	...	414	22.5	27.0	57.5	94.5
No. 7	35.9	29.5	....	130	179	202	225	244	262	279	300	320	348	373	...	24.0	27.5	62.0	....
No. 8	35.6	30.51 30.66	....	116	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	356	...	402	22.0	26.5	57.0	97.0
		30.33 30.50	....	117	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	356	...	400	21.5	26.0	59.5	97.0
No 9	35.9	29.5	59.1	118	178	208	230	250	268	288	307	331	361	388	405	22.0	26.0	58.5	95.5

[a] Did not report.

[b] Did not report 10-per-cent temperatures.

TABLE I.—*Continued*

Laboratory	Gravity of Crude, deg. A. P. I.	Per Cent off at 392° F.	Gravity of Cut, deg. A. P. I.	Initial Boiling Point of Cut, deg. Fahr.	Distillation Temperature, deg. Fahr.											Distillation Values, per cent			
					10 per cent	20 per cent	30 per cent	40 per cent	50 per cent	60 per cent	70 per cent	80 per cent	90 per cent	95 per cent	End Point	212° F.	221° F.	284° F.	392° F
LIGHT CADDO CRUDE OIL																			
No. 1..........	40.1	30.0 29.3	56.3 56.4	144	226	254	274	292	308	322	337	354	378	397	420	7.5	9.2	36.0	94.3
		29.3 29.7	56.6 56.3	146	226	254	272	290	307	323	336	355	380	398	424	7.3	9.0	36.4	94.0
No. 2..........	40.0	28.1 28.0	*a*	142	220	250	270	288	302	319	334	351	374	397	416	8.0	10.0	38.5	94.5
		28.2 28.1	*a*	140	228	252	273	290	304	319	334	352	375	392	415	7.0	8.5	36.0	96.0
		28.3 28.1	*a*	141	225	251	272	290	302	320	334	352	374	395	415	7.5	8.5	37.0	95.0
No. 3..........	40.1	27.67	56.5	144	*b*	*b*	*b*	*b*	*b*	*b*	*b*	*b*	*b*	*b*	414	6.0	8.5	38.5	94.0
No. 5..........	40.1	28.0 28.0 28.33	55.9 55.9 55.9	151	*b*	*b*	*b*	*b*	*b*	*b*	*b*	*b*	374	...	423	6.0	9.0	39.0	95.0
No. 6..........	40.0	29.1 29.1	56.1	140	223	250	270	288	305	323	338	354	378	...	418	7.0	9.5	38.0	93.5
No. 7..........	40.0	28.7	....	160	230	253	275	290	304	317	336	353	380	403	...	5.0	7.0	38.0	....
No. 8..........	40.0	28.6 29.0	....	158	*b*	*b*	*b*	*b*	*b*	*b*	*b*	*b*	369	..	408	6.0	8.6	38.0	96.5
		28.33 28.66	....	150	*b*	*b*	*b*	*b*	*b*	*b*	*b*	*b*	372	...	412	5.9	7.5	38.5	95.5
No 9..........	40.1	27.5	55.9	147	226	253	273	291	305	322	336	354	376	401	419	6.5	8.5	36.0	94.0

[a] Did not report.

[b] Did not report 10-per-cent temperatures.

TABLE II.—RESULTS OF TESTS FOR NAPHTHA CONTENT OF CRUDE OILS BY VARIOUS METHODS, RUNNING TO 392° F.

Laboratory	Gravity of Crude, deg. A. P. I.	Per Cent off at 392° F.	Gravity of Cut, deg. A. P. I.	Initial Boiling Point of Cut, deg. Fahr.	Distillation Temperature, deg. Fahr.											Distillation Values, per cent				Method
					10 per cent	20 per cent	30 per cent	40 per cent	50 per cent	60 per cent	70 per cent	80 per cent	90 per cent	95 per cent	End Point	212° F.	221° F.	284° F.	392° F.	
LIGHT CALIFORNIA CRUDE OIL																				
No. 1.......	26.5	22.3	53.2	140	206	226	242	256	271	286	306	326	356	386	417	13.4	17.5	58.7	96.0	Campbell
		22.7	52.9	140	205	224	242	256	270	286	303	324	354	384	420	13.8	17.9	58.8	96.2	
		23.8	52.8	130	202	226	242	256	272	288	306	326	352	371	393	14.0	18.0	57.8	98.0	Union Oil Co.
		23.6	53.0	132	200	225	242	257	272	287	307	326	354	372	398	13.8	17.9	57.7	93.0	
No. 2.......	26.5	22.5	....	114	199	226	242	257	271	290	307	326	350	372	395	14.5	18.5	56.5	97.5	Standard Oil Co. of California
		23.5	....	132	200	224	242	255	270	287	305	322	348	365	388	14.5	19.0	58.5	....	
		23.0	....	128	198	225	241	256	272	288	304	324	350	370	396	14.5	19.0	57.0	97.5	
No. 7.......	26.5	23.9	....	144	206	226	244	259	274	290	307	326	354	378	...	13.0	17.0	56.5	....	Campbell
No. 8.......	26.5	21.7	....	194	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	372	...	416	6.5	10.5	52.0	97.5	Campbell
		27.24	....	139	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	368	...	404	11.0	15.5	52.5	96.5	Texas Co.
		27.76	....	134	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]	362	...	398	12.0	16.0	50.0	97.5	
No. 9.......	26.7	20.6	53.3	183	210	226	241	253	266	282	298	316	345	369	394	11.0	16.0	61.0	97.0	Campbell
		22.0	53.7	131	201	223	239	253	268	284	302	324	354	383	408	15.0	19.5	60.0	96.0	Standard Oil Co. of New Jersey[a]
MID-CONTINENT PIPE LINE OIL																				
No. 1.......	35.8	29.0	59.0	112	178	208	230	247	264	282	302	322	354	380	413	21.8	26.2	60.2	96.0	Campbell
		29.4	59.0	112	180	208	230	248	266	284	302	324	357	384	416	22.0	26.0	60.0	96.2	
		30.0	59.0	112	180	210	230	248	267	285	304	326	352	370	396	21.0	25.5	59.8	98.1	Union Oil Co.
		30.2	58.8	110	178	209	229	247	266	284	304	325	352	370	396	21.5	26.0	60.0	98.0	
No. 2.......	35.7	30.0	....	115	179	210	231	251	268	286	306	326	349	366	387	21.0	25.5	59.0	....	Standard Oil Co. of California
		30.1	....	114	178	210	231	250	267	287	306	322	350	368	394	21.0	25.0	58.5	97.5	
		30.8	....	116	179	209	230	252	268	288	307	325	351	365	396	21.0	25.5	59.0	97.0	

[a] This is the proposed method modified as used by the Standard Oil Company of New Jersey for routine testing; using a 700-cc. charge in a 1000-cc. Engler type flask.
[b] Did not report 10-per-cent temperatures.

TABLE II.—*Continued.*

Laboratory	Gravity of Crude, deg. A. P. I.	Per Cent off at 392° F.	Gravity of Cut, deg. A. P. I.	Initial Boiling Point, of Cut, deg. Fahr.	Distillation Temperature, deg. Fahr.											Distillation Values per cent.				Method
					10 per cent	20 per cent	30 per cent	40 per cent	50 per cent	60 per cent	70 per cent	80 per cent	90 per cent	95 per cent	End Point	212° F.	221° F.	284° F.	292° F.	
MID-CONTINENT PIPE LINE OIL—*Continued*																				
No. 7	35.9	29.8	....	130	180	240	229	246	265	282	302	322	350	373	...	22.0	26.0	61.0	....	Campbell
No. 8	35.6	26.5	....	192	*b*	*b*	*b*	*b*	*b*	*b*	*b*	*b*	372	...	410	2.0	4.5	43.5	96.0	Campbell
		33.55	....	117	*b*	*b*	*b*	*b*	*b*	*b*	*b*	*b*	362	...	402	19.5	24.0	55.0	98.0	Texas Co
		33.58	....	121	*b*	*b*	*b*	*b*	*b*	*b*	*b*	*b*	358	...	398	19.5	25.0	54.5	98.0	
No. 9	35.9	28.2	58.1	126	192	216	234	252	268	288	306	325	352	376	396	19.0	23.5	58.0	96.5	Campbell
		29.14	59.5	115	173	205	226	246	264	284	304	329	358	388	410	23.0	27.0	60.0	95.5	Standard Oil Co. of New Jersey[a]
LIGHT CADDO CRUDE OIL																				
No. 1	40.1	27.4	56.7	146	225	250	270	286	300	314	330	348	374	394	426	7.6	9.5	39.4	94.5	Campbell
		27.6	56.4	146	226	250	270	285	300	314	330	348	372	397	424	7.8	9.2	39.5	94.0	
		29.6	56.0	140	226	256	275	292	309	320	336	350	366	380	393	7.7	9.3	36.0	98.0	Union Oil Co.
		29.4	56.0	133	224	254	274	290	306	318	334	348	364	379	396	7.5	9.0	35.9	97.9	
No. 2	40.0	29.0	....	145	228	257	276	292	306	321	334	350	368	381	402	7.5	8.5	37.5	95.0	Standard Oil Co. of California
		29.1	....	141	225	256	274	292	304	320	334	350	370	396	416	7.0	8.5	36.0	96.0	
		28.5	....	142	226	255	275	293	305	323	331	349	370	388	410	7.5	8.5	36.5	95.0	
No. 7	40.0	27.8	....	160	228	251	269	286	297	311	328	344	360	380	...	6.0	8.0	38.5	....	Campbell
No. 8	40.0	26.2	....	200	*b*	*b*	*b*	*b*	*b*	*b*	*b*	*b*	368	...	400	1.0	2.0	32.5	97.0	Campbell
		32.34	....	150	*b*	*b*	*b*	*b*	*b*	*b*	*b*	*b*	369	...	396	6.0	8.0	35.5	97.5	Texas Co.
		32.35	....	146	*b*	*b*	*b*	*b*	*b*	*b*	*b*	*b*	372	...	398	6.5	9.5	34.0	97.5	
No. 9	40.1	26.6	55.4	185	235	255	275	291	306	320	334	349	370	390	412	2.0	4.0	35.5	95.5	Standard Oil Co. of New Jersey[a]
		27.5	55.9	147	226	253	273	291	305	322	336	354	376	401	419	6.5	8.5	36.0	94.0	

[a] This is the proposed method modified as used by the Standard Oil Company of New Jersey for routine testing: using a 700-cc. charge in a 1000 cc. Engler type flask.

[b] Did not report 10-per-cent temperatures.

now operating. In individual instances, this can be regulated by stipulations of the contract between buyer and seller. (2) In any determination involving the purchase price of crude oil, it is desirable to have more than one determination of the naphtha content. For routine testing, a larger charge, for example, 700 cc. in a 1000-cc. flask, can be used. (3) A method which functions as a dehydrating apparatus and a fractionating apparatus and is also simple in construction and operation has not been found. If simplicity with a measure of accuracy is desired, it should not be expected that dehydration of refractory crude oils can be obtained at the same time. Some doubt was expressed as to whether or not it would be possible to agree upon any means of determining the kerosine content of a crude oil, or whether or not there is such a factor independent of the refinery equipment in which the crude oil is to be run.

Table II shows results obtained by members of the sub-committee with the usual apparatus of their laboratories. Although it can be seen that these methods yield larger percentages of naphtha than the proposed tentative method, the agreement among them is not very good, and all of the methods are more elaborate than the proposed method.

Respectfully submitted on behalf of the sub-committee,

A. J. KRAEMER,
Chairman.

REPORT OF SUB-COMMITTEE XXIII ON CARBON RESIDUE

Since the publication of the Tentative Method of Test for Carbon Residue (D 189 – 27 T) a few minor corrections in the text have been approved by the sub-committee. Also some additional work has been carried on to prove the applicability of the method to the testing of other oils for the various purposes for which it is recommended.

Early this year a set of four samples designated A, B, C and D, representing a wide range of carbon residues, was sent out to the membership of the sub-committee with the request for a report "following closely the revised method D 189 – 27 T." Later, sample *E* was tested by three laboratories. The results are recorded in Table I.

TABLE I.—RESULTS OF CARBON RESIDUE TESTS (REVISED CONRADSON METHOD AND APPARATUS).

	Laboratory No. 1			Laboratory No. 2			Laboratory No. 3		Laboratory No. 4	Laboratory No. 5	Laboratory No. 6		
	Operator No. 1	Operator No. 2	Average	Operator No. 1	Operator No. 2	Average	Operator No. 1	Average	Average	Average	Operator No. 1	Operator No. 2	Average
Sample A	0.126 0.133	0.138	0.13	0.12 0.12	0.12 0.13	0.12	0.17 0.15	0.16	0.16	0.14	0.16	0.185 0.155	0.17
Sample B	0.855 0.906	0.90	0.89	0.77 0.84	0.80 0.76	0.79	1.01 0.98 0.95	0.98	0.91	0.91	0.91 0.90	0.99	0.93
Sample C	2.76 2.82	2.88 2.68	2.79	2.91 2.91	2.87 2.63	2.83	3.05 3.06	3.05	3.23	3.10	2.99	3.11[a] 2.94[b]	3.01
Sample D	3.80 3.91	3.88 3.81	3.85	3.90 3.83	3.57 4.07	3.84	4.22 4.22	4.22	4.38	4.17	3.99 4.17 4.10[c]	4.21	4.12
Sample E	.....	.....	....	.....	.....	....	0.32 0.36	0.34	.....	0.34	0.34	0.36 0.35	0.35

[a] Total time of test 26.5 minutes. [b] Total time of test 27.0 minutes. [c] Total time of test 26.0 minutes.

Laboratory No. 6, not a member of the sub-committee, kindly requested a series of the samples and was supplied with the remaining portions of those tested in the laboratory of the chairman whose results are recorded under Laboratory No. 3.

A report on another sample was kindly furnished by a chemist outside the sub-committee. In one of his laboratories, carbon residues of 1.94, 1.89, 1.90 and 2.00 were obtained, averaging 1.93; in a second laboratory, 1.74, 1.80 and 1.83, averaging 1.79; in a third, 1.84 and 1.99, averaging 1.91; and the results from a fourth laboratory averaged 1.91. These are interesting as check determinations besides adding another stock to the range already tested.

A series of experiments was carried out in the laboratory of the Tide Water Oil Co. to learn what, if any, difference in percentage of residue might follow the use of hoods of different heights, with the following results:

	CARBON RESIDUE, PER CENT		
	149-MM. CHIMNEY (LONG)	125-MM. CHIMNEY (SHORT)	NO CHIMNEY
Sample A	0.24	0.23	0.22
	0.31	0.27	
Average	0.28	0.25	
Sample B	0.53	0.52	0.47
	0.58	0.56	
Average	0.55	0.54	
Sample C	1.50	1.52	1.37
	1.55	1.57	
Average	1.52	1.54	

These results show that the effect of the use of the long and short chimneys is not greater than the experimental error of the method.

In one test in the Rochester laboratory where the initial heating was somewhat too strong so that the total time of the test was 26 minutes, the carbon residue found was 0.95 per cent. The experiment was repeated giving the full time of 30 minutes and the carbon residue found was 1.00 per cent.

The report of the observations of three operators on a number of routine samples of different grades, run in duplicate, are of interest enough to report here. Operator A ran 10 samples with variations between the first and second runs of from 0.2 per cent to 20.6 per cent. The next largest deviation was 11.8 per cent, and the average deviation from the mean on the ten samples was 6.48 per cent. The actual percentages of carbon residue on these several samples ran from 0.631 to 1.583 per cent.

Operator B ran 30 samples in duplicate, the variations showing from 0.1 per cent to 17.4 per cent, but the average deviation from the mean was 4.49 per cent. The range of carbon residue in this series ran from 0.499 to 1.841 per cent.

Operator C tested 14 samples in duplicate, with a range of from 0.1 per cent between tests to 19.0 per cent, with an average deviation of 7.24 per cent. The oils showed from 0.127 to 1.558 per cent carbon residue.

There was no interchange of samples between the operators, but each one shows that the tolerance of 10 per cent as an average deviation is fair.

The sub-committee recommends that the Tentative Method of Test for Carbon Residue (D 189 – 27 T) be advanced to standard with minor revisions as indicated in the body of the report of Committee D-2.

Respectfully submitted on behalf of the sub-committee,

FLORUS R. BAXTER,
Chairman.

REPORT OF SUB-COMMITTEE XXVIII ON AUTOGENOUS IGNITION OF PETROLEUM PRODUCTS

A meeting of this sub-committee was held at the Underwriters' Laboratories, Chicago, September 26 to 30, 1927. The object of this meeting was to consider the various forms of apparatus and methods of test used by various investigators and organizations for the determination of the apparent ignition temperatures of liquid petroleum products, with a view to reaching agreement on a standard method whereby concordant results upon the same material might be obtained by different observers in different localities, the results so obtained to indicate the lowest temperature at which ignition could take place under practical conditions. The large divergence in the values obtained by different observers using different forms of apparatus and procedure, as recorded in published matter including books and periodicals, indicated the importance, and indeed, the necessity for selecting a standard apparatus and procedure, especially since the temperature of ignition is one of the vital factors bearing upon the hazard of a material.

All facilities for the efficient conduct of tests were made available to the committee through the courtesy of Mr. Dana Pierce, President of the Underwriters' Laboratories. It was at the suggestion and invitation of Mr. Pierce that the committee was in a position to carry on its experimental program. The forms of apparatus used in the tests were the following:

1. The Moore Ignition Meter;
2. The apparatus used by the Factory Mutual Laboratories;
3. The apparatus used by the General Electric Co.;
4. The Underwriters' Laboratories apparatus.

The Moore apparatus is described in the *Journal* of the Society of Chemical Industry, Vol. 36, February 15, 1917, as follows:

> The instrument consists of a diffusion block of 4-in. diameter mild steel bar 3¼ in. deep, the base of which has been turned in order to afford a greater heating surface. The upper end of the bar has been machined so as exactly to fit the platinum crucible used for the estimation of the coking values of oils (dimensions, upper diameter 35 mm., diameter of base 22 mm., height 37 mm.).
>
> A screwed-on cover protects the upper end of the crucible from draughts. This cover is provided with two holes, one for oxygen or air inlet and one for oil inlet. The oxygen or air is preheated to the temperature of the experiment, passing through a thin copper coil situated in a chamber inside the block.
>
> A thermometer and a thermocouple pyrometer are fitted into the diffusion block as close as possible to the base of the platinum crucible and serve to show the temperature of the experiment.

The method of operation when determining values in oxygen is to pass the gas through the apparatus at a speed of three bubbles per second. The quantity of oxygen is observed by means of a wash bottle filled with sulfuric acid, which also serves as a drying agent. When the temperature of the block is constant at a desired temperature, one drop of the fuel under examination is allowed to fall through the hole in the center of the cover of the instrument. If the temperature is much higher than the ignition point a sharp explosion will occur almost immediately; if below the ignition point no explosion takes place. When only slightly above the temperature of ignition, the explosion follows some 10 to 12 seconds after the introduction of oil.

By repeating the experiment the lowest temperature at which ignition takes place is rapidly determined. This temperature is the temperature of spontaneous ignition. The results obtained by different experimenters using the same instrument agree to within 3° C.

A similar procedure using air instead of oxygen will give the ignition temperatures in air, but in this case the explosion is much less violent and always follows one second after introduction of the oil.

A complete apparatus corresponding to this description and to the drawing which accompanied it, was prepared in the shops of the Laboratories. The other forms of apparatus included in the tests were as follows:

The Factory Mutual Laboratories Apparatus.—This apparatus consists of a steel disk 5 in. in diameter and $1\frac{1}{2}$ in. thick, with concentric grooves on the under side to facilitate the exchange of heat from a gas burner. The upper surface is provided with a circular groove $\frac{1}{8}$ in. deep, $\frac{1}{8}$ in. wide and $4\frac{1}{2}$ in. in diameter into which is fitted a sheet metal cylinder 5 in. high. The cylinder is insulated by means of sheet asbestos and is provided with a cover of asbestos board having a $\frac{1}{2}$-in. hole in its center for the introduction of the fuel. For temperature measurement, a $\frac{1}{8}$-in. hole is drilled through the side of the disk terminating at its center $\frac{1}{16}$ in. below the upper surface which is slightly dished.

The General Electric Co. Apparatus.—The apparatus of the General Electric Co. consists of a cylindrical steel block $5\frac{3}{16}$ in. in diameter and 4 in. in height, constructed in two sections held in place by means of six $\frac{1}{4}$-in. bolts. The upper section or cover is 1 in. in thickness. The ignition chamber is cylindrical $1\frac{1}{2}$ in. in diameter and extending $\frac{3}{4}$ in. into the upper section or cover and 1 in. into the lower section of the block. The ignition chamber is surrounded with a round annular groove of $3\frac{1}{2}$-in. outside diameter and $3\frac{3}{16}$-in. inside diameter cut into both the upper and lower sections of the block. A $\frac{1}{8}$-in. pipe is threaded into the block at the junction of the two sections so as to connect to the annular groove. A channel $\frac{5}{16}$-in. in diameter is cut between the annular groove and the ignition chamber at a point diametrically opposite the threaded pipe entering the annular groove. When in use, a slow stream of air is allowed to flow into the ignition chamber by way of the inlet pipe and annular groove. The upper section or cover is provided with a hole $\frac{5}{16}$ in. in diameter centrally located for introduction of the sample to the ignition chamber. The upper section is also provided with two $\frac{1}{4}$-in. holes diametrically opposite and passing into the lower section between the ignition chamber and the annular groove.

The Underwriters' Laboratories' Apparatus.—As this apparatus is described in detail in the proposed Tentative Method of Test appended to the report of

Table I.—Results of Tests on Autogenous Ignition, Using Various Types of Apparatus.

Apparatus							Minimum Ignition Temperature											
Type of Apparatus	Ignition Chamber			Heat Transfer Medium	Source of Heat	Method of Introduction of Sample	70–72° A. P. I. Gasoline				Motor Gasoline (Red Crown)				Turpentine			
	Volume	Shape	Material				Volume Introduced[b]	Ignition Temperature		Lag, seconds	Volume[b] Introduced	Ignition Temperature		Lag, seconds	Volume Introduced[b]	Ignition Temperature		Lag, seconds
								deg. Cent.	deg. Fahr.			deg. Cent.	deg. Fahr.			deg. Cent.	deg. Fahr.	
Moore's Ignition Meter	1.59 cu. in. 26 cc.	Crucible	Platinum	Steel block	Gas flame	Pipette	1 to 4 drops	...	...	..	1 to 4 drops	...	...	..	....	...	...	..
						Hypodermic needle	1 to 4 drops	...	...	..	1 to 4 drops	...	...	..	....	...	...	..
	1.68 cu. in. 27.5 cc.	Crucible	Steel	Steel block	Gas flame	Hypodermic needle	....	...	...	..	1 drop	402	756	..	1 drop	298	568	..
Factory Mutual Laboratories	77.5 cu. in. 1270 cc.	Cylindrical	Steel and tin plate	Steel block	Gas flame	Medicine dropper	....	413	775	..	....	385	646	..	....	...	...	..
General Electric Co.	3.1 cu. in. 50.8 cc.	Cylindrical	Steel	Steel block	Gas flame	Pipette	1 drop 0.03 cc.	331	628	..	1 drop 0.03 cc.	310	590	..	....	...	...	..
						Hypodermic needle	0.016 cc.	...	...	..	0.016 cc.	296	567	..	0.016 cc.	280	536	..
Underwriters' Laboratories	9.76 cu. in. 160 cc.	Conical flask	Pyrex glass	Solder bath	Gas flame	Pipette	3 drops 0.1 cc.	313	595	..	3 drops 0.1 cc.	274	525	..	5 drops 0.17 cc.	257	495	25
						Hypodermic needle	0.07 cc.	306	583	..	0.07 cc.	266	511	..	....	...	...	..
			Pyrex glass[a]	Solder bath	Gas flame	Pipette	3 drops 0.1 cc.	306	583	75	3 drops 0.1 cc.	285	545	..	....	...	...	..
			Iron	Solder bath	Gas flame	Pipette	3 drops 0.1 cc.	278	532	..	3 drops 0.1 cc.	245[c]	473	34	5 drops 0.17 cc.	244	471	5
			Iron[a]	Solder bath	Gas flame	Pipette	3 drops 0.01 cc.	272	522	15	3 drops 0.1 cc.	245	473	30	....	...	...	..
			Quartz	Solder bath	Gas flame	Pipette	3 drops 0.1 cc.	295	563	..	3 drops 0.1 cc.	268	514	..	5 drops 0.17 cc.	252	486	18
	18.3 cu. in. 300 cc.	Conical flask	Pyrex glass	Solder bath	Gas flame	Pipette	4 drops 0.13 cc.	287	549	20	4 drops 0.13 cc.	265	509	..	....	...	...	..
	9.76 cu. in. 160 cc.	Conical flask	Copper	Solder bath	Gas flame	Pipette	3 drops 0.1 cc.	277	531	30	3 drops 0.1 cc.	262	504	60	4 drops 0.13 cc.	264	...	..
			Copper[a]	Solder bath	Gas flame	Pipette	....	...	...	..	3 drops 0.1 cc.	275	527	55	....	...	...	..

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[a] After thorough cleaning.

[b] Shows volume introduced at lowest ignition temperature obtained.

[c] Same value obtained next day.

Committee D-2, only a very brief description is given here. It consists essentially of a small conical flask of about 160-cc. capacity (glass, quartz, steel, or copper), heated by means of a solder bath which in turn is heated by a gas flame, the temperature being controlled by regulating the flow of gas and measured by means of a thermocouple or mercury thermometer in the solder. This apparatus, with minor modifications, has been used at the Underwriters' Laboratories for many years to determine the apparent ignition temperatures of various solids, liquids, and gases.

Temperature measurements were made with calibrated thermocouples connected with a Leeds & Northrup indicating potentiometer through a selective switch. For the General Electric Co. and the Underwriters' Laboratories' methods, noble metal couples were used. For the Moore and Factory Mutual Laboratories' methods, iron-constantin fine wire couples were employed on account of the very small holes for their reception provided by the apparatus.

For the introduction of the sample to the apparatus in all except the Factory Mutual Laboratories method, a 1-cc. graduated pipette, or a hypodermic needle was used. The latter provided a very precise measurement of the small volumes, 0.01 to 0.13 cc., used in the tests. For the Factory Mutual Laboratories method, a pipette of the "medicine dropper" form was used, no attempt being made to regulate closely the volume of liquid.

The materials tested were:

1. "High Test" Gasoline (70 to 72° A.P.I.), manufactured commercially by the Standard Oil Co. (Indiana);
2. Ordinary Motor Fuel (Red Crown Gasoline);
3. Turpentine.

The Moore Ignition Meter was used in the tests with the platinum lined container as described above, and also without the platinum lining. The results of tests are shown in the Table I. The following brief statements summarize the more important indications of the data:

The Underwriters' Laboratories apparatus gives the lowest apparent ignition temperature for each of the three samples tested.

The volume of the test vessel has an important bearing upon the results, as would be expected, theoretically, and as discussed at some length at the meeting. The Moore, the General Electric Co. and the Underwriters' Laboratories' containers, having volumes of about 27, 51 and 160 cc., respectively, gave for "Red Crown" gasoline minimum values of 402° C. (756° F.), 296° C. (567° F.) and 245° C. (473° F.). The Factory Mutual Laboratories' apparatus with the largest volume gave 385° C. (646° F.). Only a small part of the inner surface of the container (the bottom) was at the temperature indicated.

The tests with the 300-cc. flask in the Underwriters' Laboratories' apparatus indicated that the 160-cc. size regularly used gives consistent results.

No ignition was obtained with the Moore apparatus platinum lined. It was only with considerable difficulty that ignition was obtained in the steel chamber.

The nature of the material of the contact surface has a bearing upon the result. All conditions except the material of the flask being kept approximately constant, it appears that the lowest temperature for autogenous ignition was obtained when the iron flask was usedl Commercial iron varying considerably in its physical and chemica. properties, as well as being difficult to keep clean, and glass also varying in composition, it would appear advisable to adopt quartz as the standard material for the flask, but also to have at hand glass (Pyrex) and steel flasks for comparative, practical tests.

The sub-committee recommends that the Underwriters' Laboratories' Method be adopted tentatively for the determination of the autogenous ignition temperature of liquid petroleum products. Further effort will be made to obtain information on the relative hazards of petroleum products and if possible to make improvements in the apparatus and methods of testing.

Respectfully submitted on behalf of the sub-committee,

A. H. NUCKOLLS,
Chairman.

REPORT OF SUB-COMMITTEE XXX ON FUEL OIL

The sub-committee plans first to investigate the field of industrial fuel oil with respect to heavy oil through the medium of the Western Petroleum Refiners Association and the National Petroleum Association with a view to learning the characteristics of the oils likely to be encountered. It is hoped by these means to obtain information from which viscosity values can be indicated and the change of viscosity of the different grades with temperatures.

It is the concensus of opinion of the committee that the selection of a fuel oil should be primarily based upon viscosity and that the old yardstick of "gravity" now in common use be discarded entirely. Every effort should be made to have the fuel oil consumers think in terms of viscosity, which will furnish them with more reliable data as to the suitability of the oil for the purpose for which it is intended.

It is also planned to carry out laboratory work on a sediment test for the heavy oils. It is felt that a more suitable test may be desired than the present extraction test for sediment, one that will give a more representative value of the amount of material that usually settles out in storage.

It is believed that the first efforts of the sub-committee should be confined to indicating suitable tests for the different grades of industrial fuel oils, and after this has been accomplished, it should take up the preparation of broad specifications covering the different classes of fuel oil in accordance with consumers' requirements.

Respectfully submitted on behalf of the sub-committee,

HAROLD FARMER,
Chairman.

APPENDIX

THE SIGNIFICANCE OF TESTS OF PETROLEUM PRODUCTS

The rapid growth of the petroleum industry has been accompanied by the development of a variety of physical and chemical methods for the testing of petroleum products.

Physical tests are more widely used than chemical tests. This is natural in view of the fact that the utility of petroleum products depends to a large extent upon their physical characteristics. Some of these physical tests are of little value except as they serve the refiner in controlling manufacturing processes, while others are useful both to consumer and to manufacturer as an index of the value or fitness of products for particular uses.

Such chemical tests as now exist serve principally to protect against impurities or undesirable constituents. This is because petroleum is an extremely complex raw material, varying greatly in composition in the various producing fields, with each new field bringing its own peculiar problems. Little is known about the chemistry of petroleum at the present time, but it may reasonably be expected that a considerable advance along this line will be made in the future.

The proper choice of tests and the assignment of proper numerical values to specifications based upon these tests is of fundamental importance. Failure to meet this requirement tends to increase the cost of the product to the consumer and adds to the burdens of the manufacturer.

The activity of Committee D-2 on Petroleum Products and Lubricants of the American Society for Testing Materials has resulted in the standardization of the more important of the older tests. This work has been of particular importance because the empirical nature of many of the tests renders it necessary to specify details of procedure which are essential to ensure uniformity of results. The committee has also developed many new tests and is continuing its work in this field.

The purpose of this report is to meet the need for authoritative information regarding the applicability of the tests for petroleum products and lubricants now in common use in this country, and the significance of results obtained.

The following topics are considered in the order named:

Gravity (page 481);
Color (page 483);
Cloud and Pour Points (page 484);
Melting Point of Paraffin Wax and Petrolatum (page 485);
Viscosity (page 486);
Consistency (page 489);
Volatility (page 493);
Tests for Illuminating Oils (page 502);
Wick Feed Test (page 505);
Water and Sediment (page 505);
Precipitation Tests (page 507);

Emulsification (page 508);
Oxidation at High Temperatures (page 509);
Dielectric Strength (page 510);
Carbon Residue (page 511);
Acidity in Gasoline (page 511);
Neutralization Number (page 512);
Total Sulfur or Sulfur Content (page 513);
Doctor Test (page 515);
Corrosion Tests (page 516);
Protection Test (page 517);
Saponification Number (page 518);
Analysis of Grease (page 519).

GRAVITY

The gravity of a petroleum oil is a numerical value which is an index of the weight of a measured volume of the product. There are two scales in general use in the petroleum industry, the specific gravity scale and the A.P.I. gravity scale.

The specific gravity of an oil is, according to the general custom of this country, the ratio of the weights of equal volumes of oil and water, both weights being determined with the liquid at a temperagure of 60° F. (15.56° C.) and both weights being corrected for the buoyant effect of air. The temperature limitations are indicated conveniently by the expression "Specific Gravity 60/60° F." An exception to this general rule exists in the case of petroleum products used as asphalts and road oils. For these products it is standard practice to use the temperature of 77° F. instead of 60° F.

The A.P.I. gravity of an oil is a mathematical function of the specific gravity, as defined above. The relationship is indicated by the following equation:

$$\text{Degrees A.P.I.} = \frac{141.5}{\text{sp. gr. } 60/60^\circ\text{ F.}} - 131.5$$

The figure 141.5 is termed the modulus of the A.P.I. scale.

Specific gravity is generally used in Continental Europe and in many other countries. It is also in rather extensive use in the United States, especially when export business is involved. The A.P.I. (American Petroleum Institute) gravity scale is generally used in the United States. It was formerly known as the Baumé scale, the name being changed to avoid confusion with the other Baumé scales, particularly the one based upon a modulus of 140.0. The A.P.I. scale differs from this Baumé scale by amounts ranging from one-tenth of one degree or less for heavy fuel oils up to seven or eight-tenths of one degree for natural gasoline.

It is of importance to point out that European practice in reporting specific gravity differs from that of the United States. The custom in Europe is to report the ratio of the weights of equal volumes of oil and water, the former at a temperature of 15° C. (59° F.) and the latter at a temperature of 4° C. (39.2° F.). The weights are not corrected for the buoyant effect of air. When specific gravities are reported according to this system, the weight of a specified volume is directly proportional to the specific gravity of the oil. When specific gravities are reported according to the system in use in the United States, calculation of the exact weight of a specified volume of oil is not so simple. This, however, is not a serious disadvantage, as the accurate and comprehensive tables[1] published by the Bureau of Standards include figures for the weights per gallon of oils of different A.P.I. and specific gravities.

The preceding statements apply to liquid petroleum products and not to solid and plastic materials such as paraffin wax and petrolatum. These materials are almost universally sold on the basis of weight instead of volume, so that tests for their gravity are relatively unimportant.

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[1] National Standard Petroleum Oil Tables, U. S. Bureau of Standards *Circular No. 154.*

Scope of Methods:

There are two general methods of determining gravity, both of which are accurate, provided apparatus and operating procedure are correct. The most important is probably the one which may be described as the constant weight-variable volume method and is exemplified by the determination with the hydrometer (see A.S.T.M. Tentative Method of Test for Gravity of Petroleum and Petroleum Products by Means of the Hydrometer (Serial Designation: D 287 – 28 T)[1]). This method involves the basic principle that when an object floats in a liquid it displaces a volume of liquid equal in weight to that of the floating mass. The hydrometer is, therefore, an instrument which measures the volume of a liquid which corresponds to its weight, and is essentially a measuring graduate with the liquid on the outside instead of the inside.

The other general type is what may be described as the constant volume-variable weight method and is exemplified by the use of the pyknometer or the hydrostatic balance.

The determination of gravity with a pyknometer involves weighing an accurately determined volume of oil in a suitable container. There are numerous types of pyknometers, the familiar specific gravity bottle being, perhaps most generally used.

Measurement of gravity with a hydrostatic balance involves determining the weight required to overcome the buoyant effect of the oil upon a totally immersed plummet of predetermined volume. The Westphal balance is an instrument especially designed for the rapid and convenient determination of this weight.

Hydrometers manufactured in the United States are calibrated to indicate gravities corrected for the buoyant effect of air. When gravities are determined with the pycnometer or hydrostatic balance, corrections must be made for the buoyant effect of air on the weights, if it is desired to obtain results identical with those indicated by the hydrometer test.

Significance and Applicability of Results:

Petroleum products are frequently sold on the basis of volumes delivered corrected to 60° F. These volume corrections are made by the use of approved tables[2] which show the magnitude of the correction as a function of the gravity of the product, regardless of its source or character. The gravity of a petroleum product must therefore be known whenever volume corrections are to be made.

In some cases, as for example the delivery of petroleum products in barrels, it is customary to determine weights and calculate volumes by dividing the weights of the contents of the barrel by the weight per gallon. The latter figure is, of course, a function of the gravity of the product.

The property of gravity is of importance in the control of refinery operations. The test is quickly and easily made and furnishes information which is useful for process control.

Gravity is of little significance as an index of the quality or usefulness of a finished product and its use in specifications is to be avoided.

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[1] See p. 924.

[2] National Standard Petroleum Oil Tables, U. S. Bureau of Standards *Circular No. 154;* A.S.T.M. Standard Abridged Volume Correction Tables for Petroleum Oils (D 206 – 25).

COLOR

The color of petroleum products is described and defined in terms of color by reflected light or by transmitted light. For the former there is no accepted quantitative measure, so that numerical units of color are based on determinations by transmitted light.

Color by transmitted light is determined in two ways:

1. Depth of oil required to match a given color standard.
2. Color standard required to match a given depth of oil.

The common commercial methods do not measure true color in its scientific sense but are largely the result of adaptation and development of simple methods originally devised to give an idea of color for comparative purposes.

The petroleum products on which color measurements are made range from those which are practically colorless to those which appear opaque when examined in the neck of a 4-oz. oil sample bottle. Commercial usage divides these products into two general classes:

1. So-called "white" products, which range from practically colorless to "pale-straw."
2. "Pale-straw" and darker.

INSTRUMENTS SUITABLE FOR "WHITE PRODUCTS"

The Society selected the Saybolt Chromometer (Tentative Method of Test D 156 - 23 T)[1] for the measurement of color of "white products." Color is determined in this method by measuring depth of oil necessary to match a standard color glass.

Other instruments used for measuring color of the same class of products are the Stammer and the Lovibond, but neither of these has been standardized by the Society.

The class of products to which the Saybolt Chromometer is applied includes: (1) Naphtha; (2) Illuminating or burning oils; (3) Pharmaceutical and technical oils; and (4) Paraffin Wax.

Significance of Results:

Color is of definite importance in case of dry cleaners' naphtha because it is essential that the naphtha be free from material which may discolor fabrics. It is also an essential quality in those cases where the naphtha is to be used as a thinner for colorless or practically colorless products.

The importance of color of a burning oil must be considered as a variable. The true index of quality of a burning oil is furnished by a burning test (see page 68); and color, even within wide ranges may have very little effect except as it may indicate contamination if original color at time of manufacture is known. Minor differences in color do not indicate any difference in burning quality. Other physical and chemical properties are of far greater importance.

Some of the uses of pharmaceutical and technical white oils require that they be water-white or nearly so. In general other requirements, such as taste and odor, necessitate a degree of refining which insures a water-white color.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 682 (1923); also 1928 Book of A.S.T.M. Tentative Standards, p. 409.

Color of wax is important and existing color requirements are based practically entirely on the experience of the user. The color of wax is always determined on the molten wax. At the present time the Society has not standardized any method for color measurement of wax and the Lovibond scale is frequently used.

INSTRUMENTS SUITABLE FOR "PALE-STRAW" AND DARKER OILS

The Society selected the Union Colorimeter (Tentative Methods of Test D 155 - 23 T[1] and D 218 - 25 T[2]) for the measurement of color of the "pale-straw" and darker products. Measurement of color by this instrument depends upon matching the color of a given depth or thickness of oil with the various color standards. In some cases where the oil is darker than the darkest color standard, provision is made for measuring the color under standardized conditions of dilution.

Other instruments commonly used for measuring color of the same products are the Tag-Robinson and the Lovibond. For their own purposes some refiners have devised instruments of more or less merit.

The class of products to which the Union Colorimeter is applied includes: (1) Spindle Oils; (2) Engine Oils; (3) Filtered Cylinder Oils; and (4) Petrolatums.

Significance of Results:

The chief significance of color as applied to this class of products lies in the fact that it is a generally accepted index of the uniformity of a given grade or brand.

Pale color is important in the case of oils used in the textile industry where staining of fabrics must be avoided.

Petrolatums for the pharmaceutical trade and manufacture of cosmetics should be of pale color to prevent staining.

Color requirements of lubricating oils are frequently over-emphasized as color does not necessarily indicate quality. A fallacy which is prevalent among consumers is that pale color indicates low viscosity.

Color requirements, by the user, should not be made any more stringent than the service demands. Adherence to this principle tends toward lower prices and conservation of natural resources.

CLOUD AND POUR POINTS

Petroleum oils become more or less plastic solids when sufficiently cooled, due either to partial separation of wax or to congealing of the hydrocarbons composing the oil. With some oils the separation of wax becomes visible at temperatures slightly above the solidification point, and when that temperature is observed, under prescribed conditions, it is known as the "cloud point." With oils in which wax separation does not take place prior to solidification, or in which the separation is not visible, the cloud point can not be determined. That temperature at which the oil just flows under prescribed conditions is known as the "pour point," irrespective of whether the cloud point is observable.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 677 (1923); also 1928 Book of A.S.T.M. Tentative Standards, p. 399.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 25, Part I, p. 713 (1925); also 1928 Book of A.S.T.M. Tentative Standards, p. 404.

Oils vary widely in these characteristics depending upon the source of the crude oil from which they are made, upon the grade or kind, and upon the method of manufacture.

Scope of Method:

The A.S.T.M. Standard Method of Test for Cloud and Pour Points (D 97 - 28)[1] prescribes conditions for the determination of these points. The test for cloud point should be used only for oils that are transparent in layers 1½ in. thick. The test for pour point can be used for all petroleum oils. For cylinder stocks and black oils, a special pour point procedure is required, and minimum and maximum values are recorded.

Significance of Results:

The cloud point is of value when the oil is to be used in wickfeed service, or when a haze or cloud in the oil above a given temperature would be objectionable for any reason. However, the test may give misleading results if the oil is not dry, due to the separation of water, and the test should always be interpreted with this fact in mind. In general, the cloud point is of more limited value and narrower range of application than the pour point.

The pour point gives an indication of the temperature below which it may not be possible to pour or remove an oil from its container, or below which it might be dangerous to use the oil in gravity lubricating systems, where the head tending to produce flow is small. However, it should be borne in mind that the size and shape of the container, the head or force exerted upon the oil, and the nature of its physical structure when solidified, all have an effect upon its tendency to flow. Accordingly, it is self-evident that no single test can be devised which can be taken as a positive and direct measure of the performance of an oil under all conditions of service, and the pour test should be regarded as giving only an indication of what may be expected.

Consequently, cloud and pour points should be interpreted in the light of actual performance under the particular conditions of use.

MELTING POINT OF PARAFFIN WAX AND PETROLATUM

The melting point of paraffin wax is the temperature at which it changes from a liquid to a solid state. The melting point of petrolatum is the temperature at which it changes from a solid to a liquid condition when the determination is made according to the prescribed A.S.T.M. method.

Scope of Method:

The A.S.T.M. Method of Test for Melting Point of Paraffin Wax (D 87 - 22)[2] involves cooling a sample of melted wax under specified conditions and noting the temperature at which a minimum rate of temperature change occurs.

Other methods for determining the melting point of paraffin wax involving the same general procedure as the A.S.T.M. method and yielding practically identical results have long been in use, among these are the Saybolt method and the so-called English method. The so-called "American Melting Point" is a figure arbitrarily taken as 3° F. higher than the A.S.T.M. melting point.

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[1] 1928 Supplement to Book of A.S.T.M. Standards, p. 133.

[2] 1927 Book of A.S.T.M. Standards, Part II, p. 409.

The A.S.T.M. Tentative Method of Test for Melting Point of Petrolatum (D 127 - 28 T)[1] involves warming a sample of petrolatum, which has previously been applied as a coating to a thermometer bulb, under specified conditions and noting the temperature at which the petrolatum becomes sufficiently fluid to leave the bulb.

Significance of Results:

The methods are used by refiners in controlling manufacture and by consumers in specifying the material desired. In general, melting point parallels hardness and it is frequently used as a substitute for a hardness test.

VISCOSITY

The viscosity of a fluid is the measure of its resistance to flow. In scientific work, viscosity is measured in terms of a unit of force designated as the "poise,"[2] while in most commercial work, an expression involving the time required for a measured volume of oil to flow, under specified conditions, through a carefully standardized tube, is known as the viscosity of the oil. To distinguish between these two methods of reporting results, the expression "absolute viscosity" is applied to an observation expressed in poises, while that expressed in terms of time of flow is designated as "viscosity," qualified, of course, as to instrument and temperature.

It is desirable, in commercial testing, that the time of flow be approximately proportional to absolute viscosity, and in order that this relationship may exist, it is necessary that the rate of flow through the tube shall not be too rapid. On the other hand the rate of flow cannot be too slow, on account of the excessive length of time required to make a test. Consequently the range of viscosity for which any particular tube can be used satisfactorily is limited as compared with the viscosity range of liquids of commercial interest in the petroleum industry, as indicated in the following tabulation:

LIQUID	APPROXIMATE ABSOLUTE VISCOSITY AT ROOM TEMPERATURE, POISES
Hexane	0.003
Commercial gasoline	0.006
Water	0.01
Kerosine	0.02
Straw oil	0.4
Automobile lubricants	1 to 10.
Cylinder stocks	40.
Heavy fuel and road oils	100. plus

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[1] See p. 931.

[2] For a detailed mathematical discussion of viscosity, see E. C. Bingham, "Fluidity and Plasticity," (McGraw-Hill) 1922; also W. H. Herschel, *Journal*, Soc. Automotive Engrs., Vol. 10, p. 31 (1922).

In practice, at least three different instruments must be employed in commercial testing: one for light distillates, one for lubricating oils, and one for heavy fuel and road oils, and actually there are two or more instruments available for each of these ranges. As previously stated, the viscosity of the oil is ordinarily expressed in terms of time, and where absolute viscosity is required, as, for example, in calculating rate of flow through tubes or pipes, or friction in a bearing, conversion into poises must be effected. Tables or curves for this conversion are available for practically all these instruments.

As viscosity changes rapidly with temperature, a numerical value of viscosity has no significance unless both the temperature and the instrument are specified. For comparative purposes, it is desirable that tests should be made at standard temperatures, as it is difficult to make conversions accurately from one temperature to another.

With certain substances, such as petrolatum, greases, and many oils containing soaps, the rate of flow is not proportional to pressure over any part of the range, the flow per unit pressure being unduly small at the lower pressures. In such instances, the term viscosity is meaningless and these substances should be considered as plastic solids rather than as viscous liquids. They are discussed in the section on consistency (see page 54).

Scope of Commercial Viscosimeters:

(*a*) *Instruments Suitable for Lubricating Oils.*—The Saybolt Universal Viscosimeter[1] (A.S.T.M. Standard Method of Test D 88 - 26[2]) is now used almost universally in the United States for the determination of the viscosity of lubricating oils. On the lighter oils the measurements are made at 100° F. or 130° F., and on the more viscous oils at 210° F. The instrument gives reliable results at any temperature between about 31° F. and 210° F., providing the oil is not near its solid point or its flash point. Above 210° F., radiation losses become so large that the results are not satisfactory, and recourse must be had to instruments such as the Ostwald type of viscosimeter, described by Bingham, which can be completely immersed in a high-temperature bath.

It should be emphasized that Saybolt viscosities, which are expressed in seconds, are not even approximately proportional to absolute viscosities except in the range above 200 seconds. As the time of flow decreases, the deviation becomes more and more marked and below 40 seconds the departure is so great that the use of Saybolt seconds as an index of absolute viscosity is very deceptive. Thus, an oil with a viscosity of 35 seconds Saybolt has about twice the absolute viscosity of one which gives a reading of 32 seconds Saybolt, and even the very lightest liquids do not give readings below about 28 seconds Saybolt. The instrument should preferably not be used on oils reading below 40 seconds, and never on oils below 32 seconds.

Other viscosimeters covering the same general range but not standardized by the Society are the Redwood No. 1, the Barbey, and the Engler instruments.[3]

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[1] For conversions to absolute viscosity see report of Committee on Viscosity Standards of the American Petroleum Institute (1922–1924).

[2] 1927 Book of A.S.T.M. Standards, Part II, p. 427.

[3] For conversion to absolute viscosity see W. H. Herschel, *Journal*, Soc. Automotive Engrs., Vol. 10, p. 31 (1922). For details of operating the Redwood instruments see Standard Methods of Testing Petroleum and Its Products, Inst. of Petroleum Technologists, p. 49 (1924).

These viscosimeters are in general less completely standardized both as to the instrument and the details of operation than the Saybolt Universal Viscosimeter.

(*b*) *Instruments Suitable for Heavy Fuel and Road Oils.*—The Saybolt Furol Viscosimeter (A.S.T.M. Standard Method of Test D 88 - 26[1]) is applicable to and generally recommended for the determination of the viscosity of heavy fuel and road oils. The temperature usually employed is 122 F. Readings above 100 seconds are roughly one-tenth of those of the Standard Saybolt instrument on a given oil at a given temperature.

Other instruments used for the same products but less completely standardized are the Redwood Admiralty and the Engler.[2] The Redwood Admiralty instrument is quite generally used in England, while the Engler was very generally used in this country on heavy oils prior to the development and standardization of the Saybolt Furol instrument.

(*c*) *Instruments Suitable for Gasoline and Kerosine.*—The Saybolt Thermo-Viscosimeter[3] and the Ubbelohde Viscosimeter[4] are used for the determination of viscosity of very light distillates, such as gasoline and kerosine. The former instrument is rather generally used by oil refineries, but cannot readily be standardized in terms of absolute viscosity. The latter is theoretically of a better type but is very little used in this country. Neither of these instruments has been standardized by the Society.

Significance of Results:

The significance of viscosity depends upon the purpose for which the oil is to be used.

For *lubricating oils* viscosity is the most important single property. In a bearing operating properly, with a fluid film separating the surfaces, the viscosity of the oil at the operating temperature is the property which determines the bearing friction, heat generation, and the rate of flow under given conditions of load, speed, and bearing design. The oil should be viscous enough to maintain a fluid film between the bearing surfaces, in spite of the pressure tending to squeeze it out. While a reasonable factor of safety is essential, excessive viscosity means unnecessary friction and heat generation.[5] Since the rate of change of viscosity with temperature varies with different oils, viscosity tests should in general be made at that standard temperature which approximates most closely the temperature of use.

For *industrial fuel oils* viscosity is of importance mainly in determining the ease of atomization in a given type of burner, and the conditions as to temperature and pressure required to supply the oil to the burner. Gravity is incorrectly used as a basis for classifying such oils with respect to viscosity.

For *road oils* viscosity largely determines the rate of distribution by a given apparatus at a given temperature, and influences the rate of penetration into a given road surface. The determination of viscosity should, therefore, be made at the standard temperature approximating that of application.

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 427.

[2] For conversion to absolute viscosity see W. H. Herschel, *Journal*, Soc. Automotive Engrs., Vol. 10, p. 31 (1922). For details of operating the Redwood instruments see Standard Methods of Testing Petroleum and Its Products, Inst. of Petroleum Technologists, p. 49 (1924).

[3] A. R. Fortsch and R. E. Wilson, *Industrial and Engineering Chemistry*, Vol. 17, p. 281 (1925).

[4] W. H. Herschel, *Proceedings*, Am. Soc. Testing Mats., Vol. XIX, Part II, p. 676 (1919).

[5] For a quantitative discussion of the effect of various factors on the viscosity required to lubricate journal bearings see R. E. Wilson and D. P. Barnard, "The Mechanism of Lubrication," *Journal*, Soc. Automotive Engrs., Vol. II, July, 1922, p. 49.

For *illuminating oils* viscosity plays only a moderate part in determining the rate of flow through a wick. The value of the test is mainly in eliminating oils of abnormally high viscosity which would not flow properly through wicks of lamps and burners of ordinary design. There is also some indication that oils of very low viscosity will give unsteady flames. The performance of burning oils is influenced less by viscosity than by tendency to attack or incrust the wick. An actual burning test is the best method of determining the quality of illuminating oil as it indicates the combined effect of all of the important properties.

For *motor fuels* viscosity has little, if any, practical significance. While changes in the viscosity of a motor fuel affect the richness of the mixture supplied in certain types of carburetor, in others the difference is negligible. As a rule the differences in mixture between different fuels of proper distillation range are much smaller than the differences produced by ordinary temperature variations.

In conclusion, viscosity should sometimes be considered in connection with various products for special uses. For example, whenever the ease or rate of circulation of an oil is important, as in the case of transformer oils or oils for circulation in heat-carrying systems, viscosity becomes a factor of practical significance. This is also true of oils which must penetrate or saturate porous material. Viscosity is also of importance in designing pipe lines and oil heat exchangers.

CONSISTENCY

The term consistency is generally considered to refer to the flow-pressure characteristics of viscous liquids and of plastic materials such as petrolatum, greases, soap-thickened oils and pitches, which occupy an intermediate position between viscous liquids and plastic solids.

The fundamental characteristic of a true viscous liquid is that its rate of flow through a narrow capillary is directly proportional to the pressure applied, so that its viscosity may be determined by a single measurement at any pressure in any properly standardized instrument, and its rate of flow through anything from another capillary to a pipe line can be calculated.

Plastic solids are materials, for example, ordinary cup greases, which are not deformed by small forces, but which flow if any considerable pressure is applied. They are characterized by requiring a certain starting pressure before flow begins, and at higher pressures their rate of flow through a capillary increases more rapidly than in direct proportion to the pressure.

A third class of materials is intermediate between plastic solids and viscous liquids. Such materials resemble liquids in that they seek their own level and in time obliterate deformation of their surface, but resemble plastic solids in that their rate of flow increases more rapidly than in direct proportion to the pressure applied. These materials, of which soap-thickened oils and rubber cements are representative, may best be classed as plastic liquids.

Since the ratio of flow to pressure is not constant for either plastic solids or plastic liquids, a single numerical value is inadequate to define the consistency of these materials. It is seldom true that two plastic materials, which give the same value under one set of tests, will be found alike under other test conditions.

The determination of the consistency of plastic materials is hampered by the complicated nature of their flow-pressure relationships and as a result, most consistency tests are highly empirical, although generally designed to bear some relationship to conditions of use. It must be also kept in mind that the consistency of plastic materials frequently changes with working or aging.

The term consistency, in the case of greases and other plastic materials, is sometimes used to include related factors which might more properly be described as differences in texture ("smooth," "fibrous," "spongy"), elasticity ("tacky," "rubbery") or ductility ("stringy," "short," "cheesy"). Practically nothing has been done on the measurement of these properties but in the case of greases they can sometimes be controlled approximately by describing the general composition.

Scope of Methods:

(*a*) *General Methods.*—Although units for expressing consistency have not been standardized, except in the case of viscous liquids, considerable progress has been made in developing apparatus and methods for determining flow-pressure curves by measuring the flow at different pressures through a capillary tube. Methods of this type are the best thus far developed to give a fairly complete picture of the behavior of plastic materials under varying conditions of shear and temperature, but the measurements are time-consuming and the necessity for using two or three variables to describe the consistency makes such methods undesirable for control tests or specifications. The apparatus and methods ordinarily employed are based mainly upon the work of Bingham and Green,[1] who developed a type of instrument called a plastometer. These methods are not suitable for measuring the unworked consistency of materials such as grease because of the working incident to putting them into a container and forcing them through a capillary. Reproducible results with such materials are best obtained by working them thoroughly before testing.

(*b*) *Methods for Greases, Petrolatum, and Similar Materials.*—The A.S.T.M. Tentative Method of Test for Penetration of Greases and Petrolatum (D 217 - 27 T)[2] is designed for use whenever a numerical expression of consistency on such products is desired. In this test a double-pitch cone of standardized weight and dimensions, supported in an asphalt penetration tester is allowed to drop into the product maintained at a definite temperature. The depth of penetration, measured in hundredths of a centimeter, is observed and reported as the penetration of the material. In recognition of the fact that the consistency of cup greases changes markedly with working, the method also includes a procedure for determining worked consistency.

Other devices for determining the consistency of greases, not standardized by the Society, are the G-H Consistency Tester, the Karns-Maag Tester, and the Abraham Consistometer. In a few cases, instruments designed and suitable only for testing liquids have been used to give some sort of figure for greases, but the results are neither reproducible nor significant. A case in point is the MacMichael viscosimeter, which the makers recommend only for liquids (including the more fluid plastic liquids).

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[1] E. C. Bingham and Henry Green, "Paint, a Plastic Material and not a Viscous Liquid; the Measurement of Its Mobility and Yield Value," *Proceedings*, Am. Soc. Testing Mats., Vol. XIX, Part II, p. 640 (1919). Several papers, *Journal Physical Chemistry*, Vol. 29, pp. 1201–1288 (1925); P. M. Porter and W. A. Gruse, *Industrial and Engineering Chemistry*, Vol. 17, p. 953 (1925).

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 930 (1927); also 1928 Book of A.S.T.M. Tentative Standards, p. 434.

(*c*) *Methods for Soap-Thickened Oils and Other Plastic Liquids.*—Although soap-thickened oils and other plastic liquids are frequently tested at elevated temperatures in the Saybolt or other viscosimeters, the results have little real significance; first, because their apparent viscosity varies with the pressure applied, and secondly, because their properties change very rapidly with temperature. Since plastic liquids usually change but little in consistency with working, the plastometer type of method is applicable. A simplification suitable for testing such products over a low pressure range is the burette consistometer, recently described in detail by Herschel and Bulkley.[1] It consists essentially of a burette to which a capillary tube has been attached. The flow varies, due to the decrease in static head as the burette empties, and by proper observations and calculations it is possible to make a flow-pressure diagram and

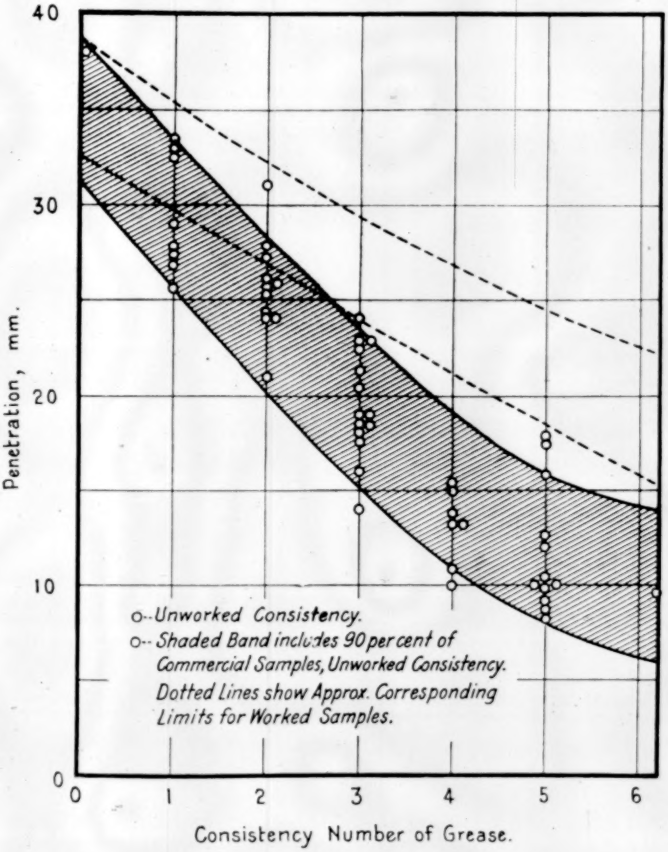

FIG. 1.—Results of Consistency Measurements of Grease from Various Manufacturers.

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[1] W. H. Herschel and Ronald Bulkley, *Industrial Engineering Chemistry*, Vol. 19, p. 134 (1927).

determine the degree of plasticity and the behavior of the oil under different shearing stresses.

The MacMichael viscosimeter[1] may be used for many such products by operating it at different speeds in order to obtain what corresponds to a flow-pressure diagram.[2] It is, however, difficult for different operators to obtain concordant results on different instruments on account of the many variables involved.

Another method is to impose different air pressures on a Saybolt viscosimeter or a similar device with interchangeable capillaries.

Significance of Results:

While the consistency of a plastic material cannot be defined by a single numerical value, it may be tentatively assumed that if the tests deal with a single class of materials and employ forces of the magnitude met with in service, the results are helpful and significant. The A.S.T.M. Penetration Test is a case in point and gives valuable information on ordinary greases. The relationship between the penetration figures and the better-known trade consistencies of grease is shown in the accompanying Fig. 1.

The consistency of a cup grease varies greatly with temperature, the amount of working, the kind and amount of fat used, the temperature of pouring, the rate of cooling and other factors. Furthermore, greases cannot be blended to consistency after manufacture. This accounts for the somewhat wide variation shown in Fig. 1 for greases of a given trade consistency. Accordingly, it is impossible for a grease manufacturer to meet close limits, particularly for unworked consistency, and if consistency limits are fixed the soap content should not be too closely specified.

The methods of utilizing both grease and petrolatum are so varied that it is impossible to generalize as to the significance of penetration results except to point out that the more fluid the grease the easier it can be fed to or squeezed out of a given bearing and the less the friction will be, down to the point at which the film is squeezed out. Greases covering a wide range of consistency or penetration are available and when a satisfactory grade has been found, the specification of the penetration and the general composition will usually insure fairly uniform behavior in service. However, two greases which vary widely in composition may behave quite differently, even though they have the same penetration.

For many of the uses of petrolatum, the penetration figure is a better measure of the properties desired than is the more widely used melting point, although melting point is generally, but not always, roughly parallel to stiffness.

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[1] W. H. Herschel, *Journal*, Optical Society of America, Vol. 7, p. 335 (1923); see also discussion of an earlier type instrument—W. H. Herschel, *Industrial and Engineering Chemistry*, Vol. 12, pp. 282, 818 (1920).

[2] G. St. J. Perrott and R. Thiessen, *Industrial and Engineering Chemistry*, Vol. 12, p. 324 (1920).

VOLATILITY

Volatility may be defined in general terms as the tendency of a product to change from the state of liquid to that of vapor. For petroleum products it is determined by means of a variety of specific tests, which for purposes of convenience are discussed under the following headings:

1. Flash and Fire Tests;
2. Distillation Tests;
3. Vapor Pressure and Evaporation Tests.

FLASH AND FIRE TESTS

The flash point of a product may be defined as the temperature to which it must be heated in order to give off sufficient vapor to form an inflammable mixture with air. The fire point may be defined as the temperature to which a product must be heated in order to burn continuously after the inflammable air-vapor mixture is once ignited. The fire point test is less frequently used than the flash point test and in a majority of instances adds nothing to the information furnished by the results of the latter.

Flash point tests were originally employed to indicate the fire hazard of petroleum products. Their use has, however, been extended and they are frequently employed to give information which does not relate to fire hazard.

The flash point of a substance varies with the apparatus and procedure employed in making the test. For this reason it is always necessary to specify apparatus and method when reporting flash point figures.

A large number of so-called "flash testers" have been devised and used. Some of the more important ones will be discussed later, but for the present it is desirable to mention the characteristics and utility of the two general classes: (1) Closed cup testers; and (2) Open cup testers.

When flash point is determined as an index of fire hazard, the closed type of tester is unquestionably preferable to the open cup type. The greatest element of danger incident to the handling or storage of petroleum products is the explosive ignition of vapors in the unfilled portions of tanks, drums or other containers. The closed cup tester permits measuring the temperature which the oil must reach before it gives off enough vapor to create an explosive mixture in a closed system, and, therefore, comes closer to paralleling actual conditions than does the open cup. In addition, closed cup testers are in general more accurate than the open cup type, which is a consideration of importance when matters of safety are involved.

The chief advantages of the open cup testers are cheapness and simplicity in operation. For many purposes the results they yield are sufficiently accurate to meet all practical requirements.

The flash points of different petroleum products vary over a wide range. The more volatile gasolines and naphthas flash at temperatures considerably below 0° F. Certain special naphthas, largely used as paint thinners and solvents, have closed cup flash points between approximate limits of 80 and 110° F. The normal closed cup flash point range for kerosine is 100 to 160° F. Gas oils and fuel oils generally have flash points between 150 and 300° F., and the majority of lubricating oils have flash points between 275° F. and 650° F.

It is theoretically possible to test the whole range of petroleum products with a single flash tester but in actual practice it has been found best to use three instruments. A closed tester with a water bath and without a stirrer in the cup is best for the naphtha-kerosine group of products. For the testing of fuel oils, gas oils, etc., a closed tester without a water bath and with a stirrer in the cup is preferred. Lubricating oils can be tested with the necessary degree of accuracy by the use of a simple open cup tester.

Scope of Flash Test Methods:

(*a*) *Instruments Suitable for Kerosine and Naphtha.*—The flash point of naphtha and kerosine is determined as an index of fire hazard and it is, therefore, essential to use a closed cup tester, designed and operated to yield the greatest possible degree of accuracy. General experience has indicated that careful control of the rate of heating is essential to accuracy and the use of a water bath as a medium for transmitting heat to the oil under test is the most effective means of accomplishing this end.

The Tag Closed Tester (A.S.T.M. Standard Method D 56 - 21[1]) meets the requirements outlined and is official with the United States Government. The Abel Closed Tester,[2] which is official with the British Government, is equally suitable and is largely used in this country by oil companies doing an export business. Its chief disadvantage, as compared with the Tag Closed instrument, is that it is considerably more expensive and not so easy to obtain. Another closed tester that is important in Europe is the Abel-Pensky, which is a modification of the Abel, equipped with an automatic timing device for the operation of the mechanism which opens the shutter and depresses the test flame.

In this country a large number of states have oil inspection laws on their statute books and most of these laws include specifications prescribing a minimum flash point limit for kerosine. A number of different testers are approved, among them the Elliott, Foster, and Tagliabue Open Cup. Of these the Elliott seems to be the best but none of them is as accurate or as convenient to use as the Tag Closed, the Abel or the Abel-Pensky instruments.

(*b*) *Instruments Suitable for Gas Oil and Fuel Oil.*—The flash point of gas oil and fuel oil is determined as an index of fire hazard, and a closed cup tester should, therefore, be used. Fuel oils frequently have high viscosities and stirring of the oil during the test is essential to insure maximum accuracy. The working ranges of temperature are too high to make practical the use of a water bath as a medium for transmitting heat.

The Pensky-Martens Closed Tester (A.S.T.M. Standard Method D 93 - 22[3]) is used almost exclusively, the world over, for determining the flash point of fuel oil and gas oil. Other instruments are of almost negligible importance, except possibly the Luchaire which is used to some extent in France. Open cup testers are sometimes used for fuel products, but usually only in cases when the oils have flash points so much above specification limits that there is no need for a high degree of accuracy.

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 300. For a detailed report of the work which led to the adoption of the Tag Closed Tester, refer to *Proceedings*, Am. Soc. Testing Mats., Vol. XVII, Part I, pp. 402–450 (1917).

[2] "Standard Method of Testing Petroleum and Its Products," Inst. of Petroleum Technologists, London, pp. 18–23 (1924).

[3] 1927 Book of A.S.T.M. Standards, Part II, p. 395.

(*c*) ***Instruments Suitable for Lubricating Oils.***—Practically all lubricating oils have flash points sufficiently high to eliminate the question of fire hazard; the use of the closed cup instrument, therefore, is not essential, and the degree of accuracy attainable through the use of an open cup is adequate for practical purposes. The Cleveland Open Cup (A.S.T.M. Standard Method D 92 - 24[1]) is almost universally used in the United States for the testing of lubricating oils, and has the desirable feature of cheapness and simplicity of equipment, adaptability to a wide range of products and adequate accuracy.

The Marcusson open cup is largely used in Europe for testing lubricating oils and gives results very close to those obtained with the Cleveland. The Pensky-Martens Closed Tester is also used very largely for testing lubricating oils and is satisfactory for all but the group of so-called cylinder oils. With these it is difficult to get satisfactory agreement between duplicate tests. The use of the Pensky-Martens tester for lubricating oils has very little practical justification, especially in view of the fact that for products of high flash point its accuracy does not exceed that of the open cup instruments mentioned above. The Pensky-Martens Tester is at its best in testing products having flash points between 150 and 230° F. From 230 to about 450° F., its accuracy may be rated as equal to that of the Cleveland Open Cup, and above 500° F. it is notoriously unreliable.

(*d*) *Instruments Suitable for Miscellaneous Products.*—There are a number of petroleum products that are not classed either as (1) kerosine and naphtha, (2) gas oil and fuel oil, or (3) lubricating oils. The proper type of flash test apparatus to be used for any of them is indicated by the general principles indicated above. Thus, for example, an asphalt or road oil which prior to use is heated in open pots to a fairly high temperature should be tested in the Cleveland Open Cup or its equivalent. A viscous crude oil of low naphtha content should be tested the same as a fuel oil, in the Pensky-Martens.

Scope of Fire Test Methods:

Fire tests should always be made with open cup instruments, by continuing the heating and applications of the test flame after the flash point has been reached. A.S.T.M. Method D 92 - 24, involving the use of the Cleveland Open Cup, includes directions for determining fire point. Certain lubricating oils, notably the so-called steam-refined cylinder stocks, are sometimes classified on the basis of fire test and this property has, therefore, some commercial importance, due to trade custom. Flash point is, however, more generally used as an index for classifying and identifying lubricating oils and is generally preferred.

Fire point requirements are occasionally encountered for kerosine. The determinations are made with instruments that are practically obsolete and the test figures themselves are of negligible value as compared to flash point figures obtained by the use of an approved type of closed-cup tester.

The whole question of fire point can be summarized by the statement that knowledge of this physical property adds little to the information that can be obtained from flash point figures. No further mention will be made of fire point in the present discussion.

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 404.

Significance of Flash Test Results:

The practical significance of the flash test as related to certain petroleum products has already been discussed in connection with the selection of suitable instruments and methods. For the class designated as kerosine and naphtha, fire hazard is the principal consideration. No one test or property is a complete index of fire hazard, but flash point is universally regarded as the most important. It is an index of the probability of ignition and under usual conditions it is more important to know whether or not a product is likely to ignite than how it will behave after it is actually afire.

In discussing fire hazard and the importance of flash test in this connection, it is impossible to avoid a question as to what particular temperature limit differentiates between safety and danger. There are wide variations in the flash point requirements for kerosine enforced by different municipalities, states and countries, and the whole proposition seems complicated and confused until a very simple basic principle is recognized. Actually, kerosine is not safe simply because it has a flash point of, say, 100° F., but it is safe because the users have learned to treat it with the degree of care which is essential for a product which can be ignited if it is warmed above this temperature. Kerosine with a flash point of 90° F. is just as safe as kerosine having a flash point of 100° F., if users are accustomed to it and are familiar with the precautions necessary in handling it. As a matter of fact it can be stated without much exaggeration that gasoline is just as safe as kerosine, provided the person using it knows that it is a volatile product capable of being ignited at any ordinary temperature. This same gasoline would, however, be a dangerous commodity in the hands of a user who thought it was kerosine.

There is, of course, a minimum safe limit for flash point, which is fixed by the conditions of temperature occurring in the equipment in which kerosine is burned. This limit, however, seems to be tolerably low, probably somewhat under the lowest figure that is specified by any of the existing American legal regulations. The requirements in effect are designed chiefly to provide safety in the storage and handling of the oil, and they accomplish this end by insuring against the marketing in a given community or district, of kerosine which flashes more readily than the product to which the users are accustomed. A great deal might be said in favor of standardizing the flash test requirements for kerosine the world over, but so much difficulty would be encountered and so little benefit derived, either by producer or consumer, that it seems best to accept the situation as it exists and recognize the fact that safety is measured by the habits of the user rather than by the physical and chemical properties of the oil.

Fire hazard is also the important consideration when gas oil or fuel oil is tested for flash point. Here again there is a relation between specified minimum flash and accepted practice in handling and use. For domestic installations the usual minimum limit for flash point is 100° F., and for commercial installations, particularly those which utilize products of viscosity sufficiently high to require preheating, the customary requirement is a minimum of 150° F.

For a large number of petroleum products, notably the class of lubricating oils, flash point is not determined as an index of fire hazard but rather for purposes of identification and classification. The interpretation of figures is not simple and as a general rule it may be said that the flash point of a lubricating oil bears no direct relation to its usefulness. Flash point tests are useful to refiners in controlling the manufacturing process. The usual practice in writing specifications is to attempt to identify certain types of oils which are known through experience to be suitable. Existing methods for determining the actual usefulness or value in lubricating oils are not satisfactory and in general it may be stated that the use of flash point limits in lubricating oil specifications is actually a makeshift to compensate for a large factor of ignorance.

The flash point of an oil may serve as a rough indication of its tendency to vaporize. The occurrence of foaming in the course of a flash point determination is a rather sensitive qualitative indication of the presence of moisture in the sample that is being tested.

DISTILLATION TESTS

A distillation test involves the general procedure of vaporizing the liquid under test and recording a set of figures indicating the relation between temperatures in the distilling vessel and quantities of distillate that have been liquified by the condenser. There are many possible variations in the details of a distillation test, both as regards apparatus and procedure, and the observations that are made. For present purposes, discussion will be confined to the general principles involved and to the two or three specific methods that are of greatest importance. The distillation test is particularly applicable to products which are vaporized in the course of their use, but also serves for identification and classification of other products.

Petroleum products are complex mixtures of hydrocarbons containing large numbers of individual compounds. When they are boiled, the vapor given off at any instant is only moderately less complex than the liquid, and is usually subjected to some sort of treatment, designed to simplify its composition, before it passes into the condenser. This treatment, which is variously referred to as fractionation, rectification, dephlegmation, etc., involves decreasing the proportion of the less volatile constituents in the vapor. Fractionation may be effected either by partial condensation, which liquifies more of the high-boiling than of the low-boiling hydrocarbons, or by allowing the vapor to come in contact with a counter current of distillate maintained at a temperature below its boiling point; or by a combination of these two effects.

Laboratory stills are occasionally encountered which operate with a practically negligible degree of fractionation; the composition of the vapor that leaves the liquid being unchanged until it enters the condenser. Such stills are not particularly useful and are rarely used.

A large proportion of the more common laboratory distillation methods involve a certain degree of fractionation, which is in general incidental and due to the cooling of the vapors in the necks of distilling flasks. This fractionation is effected chiefly by partial condensation, but there is, of course, a certain amount of contact between the reflux current of condensed distillate and the rising current of vapor. This general method of distillation does not furnish exact information as to the true boiling points of the constituents comprising a petroleum product, but it can, if properly standardized as to details of apparatus and procedure, be made to yield results that are closely reproducible. Methods of this sort have the added advantage of simplicity and convenience, and though subject to theoretical objections are, and probably always will be, the most important type used by the petroleum industry.

Oil testing laboratories are called upon from time to time to predict what products can be made in a commercial way by the fractional distillation of particular crude oils or partially refined fractions of crude oil. Many methods have been devised to provide the necessary data and the majority of them involve the use of devices intended to fractionate the vapors. These devices are commonly referred to as fractionating columns, dephlegmaters, or still heads. There are in existence a number of general types and many variations of each type. An adequate discussion of the merits of various "still heads" is beyond the scope of the present discussion.[1]

Scope of Distillation Methods:

Methods Suitable for Gasoline, Naphtha and Kerosine.—The A.S.T.M. Standard Method of Test for Distillation of Gasoline, Naphtha, Kerosine and Similar Petroleum Products (D 86 - 27),[2] is almost universally used in the United States for the products mentioned. It has been standardized in detail and is capable of a very satisfactory degree of accuracy. The A.S.T.M. Standard Method of Test for Distillation of Natural Gas Gasoline (D 216 - 27)[3] is very similar, but includes minor modifications which are desirable for the handling of the special product covered. Both of these methods are essentially the European Engler method, improved to permit attaining better reproducibility.

These methods are of the general type involving a moderate degree of fractionation effected by condensation and reflux in the neck of the flask. There are occasionally instances when gasoline or other volatile petroleum products are tested by methods involving the use of some sort of a still head, but none of these methods has been prescribed in sufficient detail to warrant considering it as standardized.

Method Suitable for Gas Oil.—The A.S.T.M. Standard Methods of Testing Gas Oils (D 158 - 28)[4] includes a procedure for the distillation of gas oil. This method is similar in principle to those mentioned above but involves the use of a somewhat larger flask and a larger quantity of oil. This method has been developed for the purpose of obviating the difficulties encountered when an attempt is made to distill gas oil according to the procedure which has been adopted for naphtha and kerosine.

Methods Suitable for Crude Petroleum and for Unfinished Petroleum Products.—The A.S.T.M. Tentative Method of Test for Distillation of Crude Petroleum (D 285 - 28 T)[5] outlines apparatus and procedure for determining the percentage which distills below some selected temperature point. This method is intended to provide information as to the relative gasoline contents of different crude oils and does not cover a procedure for the complete assay of a crude oil sample.

Bureau of Mines *Bulletin No. 207*[6] describes a procedure which was devised for determining the general characteristics of crude oil samples. This method has been rather extensively used and data on the properties of a large number of crude oils are available, as determined by this method. It is not, however, a method designed to give results in terms of commercial refining operations, and although it has, with suitable modifications, been used for this purpose, these modifications or simplifications have not been given any official recognition.

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[1] See "Distillation Principles and Processes," by Sydney Young, MacMillan and Co., London (1922).

[2] 1927 Book of A.S.T.M. Standards, Part II, p. 378.

[3] *Ibid.*, p. 387.

[4] 1928 Supplement to Book of A.S.T.M. Standards, p. 156.

[5] See p. 917.

[6] "The Analytical Distillation of Petroleum and Its Products," by E. W. Dean, H. H. Hill, N. A. C. Smith and W. A. Jacobs, U. S. Bureau of Mines *Bulletin No. 207*, 1922.

Another well-known method for the distillation assay of crude petroleum is the so-called Four Point Control Method[1] which was developed primarily for the purpose of estimating the percentage of U. S. Government Standard Motor Gasoline in California crude oil.

Numerous other methods have been developed and used, but are not covered by published descriptions. Practically all involve the use of stills equipped with fractionating columns, and many of the variations are due to the fact that the methods were devised for the purpose of duplicating the yields and qualities commercially obtained by some specific refinery.

Significance of Results:

Distillation tests yield results which are expressed in terms, not of one, but a number of figures. The discussion of the significance of results is therefore complicated by the fact that a given test may tell a number of things, some of which are significant and some not. For present purposes an attempt will be made to discuss in detail the significance of distillation results as applied to several products. The general principles illustrated can be applied to other products.

Motor Gasoline.—The general requirements for volatility of motor gasoline are:

1. (*a*) The gasoline should contain enough readily volatile constituents to permit starting an engine under reasonably unfavorable conditions, without preheating. It should also be possible to operate the engine with a reasonable degree of flexibility during the period while it is warming up to optimum operating temperature.

(*b*) The gasoline should not contain so large a percentage of highly volatile constituents as to be liable to excessive evaporation losses or to premature vaporization in carburetors or fuel lines.

2. The gasoline should not contain any considerable percentage of relatively heavy, slightly volatile constituents which will not, under ordinary conditions, vaporize completely enough after atomization into the manifold to permit even distribution to the various cylinders of any engine. These heavy ends are also undesirable because they tend to dissolve in the oil on the cylinder walls and increase dilution of the oil in the crank case, although the design and method of operation of the car also has an important effect upon the amount of dilution.

These general requirements are taken care of by specifying:

(*1*) *a*. That the gasoline contains an adequate percentage of constituents distilling below some moderately low temperature. This is usually accomplished either by specifying a maximum temperature for 20 per cent off or a minimum percentage off at 100° C. (212° F.). Limits of this type insure the presence of sufficient low-boiling material to permit satisfactory starting of engines.

b. The exclusion of an excessive proportion of highly volatile or "wild" constituents can be effected in several ways. The most satisfactory and effective requirement is a minimum permissible recovery of distillate in the receiving graduate at the end of the test. This in effect limits the percentage that cannot be liquefied in passing through the condenser tube and thereby differentiates in a practical way between desirable and undesirable volatile constituents.

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[1] Howard C. Vesper, ***Industrial and Engineering Chemistry***, Vol. 18, pp. 64–67 (1926).

(2) The presence of high-boiling constituents is usually limited by specifying a minimum permissible percentage which distills below some temperature, such as 392° F., well up in the normal distillation range of gasoline. It is also general practice to place a maximum limit on end point. There is no definite evidence that both of these points need be specified and the percentage at a selected high temperature is the more significant. The common practice of grading gasoline on the basis of end point cannot be endorsed, because end point alone is an unreliable criterion of quality.

Natural Gas Gasoline.—The three factors of volatility that are of importance with natural gas gasoline are:

1. Percentage distilling below 100° C. (212° F.) or other temperature used as the reference point for the motor gasoline or naphtha which is to be made by blending the natural gas gasoline with less volatile refinery stock.
2. Freedom from more than traces of absorbent oil.
3. Minimum content of constituents which are excessively volatile.

The first requirement is taken care of satisfactorily by specifying a minimum percentage at 100° C. (212° F.). The second requirement is taken care of by specifying maximum end point, and the third requirement is covered by specifying a minimum percentage for recovery of liquid products at the end of the distillation.

Kerosine.—The distillation of kerosine does not yield much information of value except possibly in cases when it is necessary to ascertain the presence of fractions of excessively high boiling point, which may tend to clog or crust the wick of a burner. Kerosine is sometimes used as a fuel for internal combustion engines and in such cases the volatility requirements bear a certain degree of similarity to those of gasoline.

Gas Oil.—So-called gas oils are used for a variety of purposes. The name originally signified that they were suitable for carbureting and enriching manufactured gas, and this is still an important use. Gas oil is also an important raw material for the manufacture of gasoline by cracking processes. It is sometimes employed as fuel oil for the generation of heat and power and is used as fuel for the types of internal combustion engines generally classified as heavy oil engines.

The significance of volatility in relation to these uses is not definitely established and the most important function of the distillation method, as applied to gas oil, is to determine its suitability for cracking in processes of the pressure distillation type. A distillation test gives a rough index of the pressure-temperature curve and tells whether, with a predetermined maximum working pressure, it is possible to heat the oil hot enough to effect satisfactory conversion into gasoline.

No reliable information seems to be available regarding the influence of volatility upon the performance of gas oil used as fuel in heavy oil engines. The present tendency of designers of this sort of equipment is to build engines which will burn any sort of oil that can be injected into the cylinders in a proper state of atomization.

Manufacturers of carbureted water gas seem to regard the distillation test as of some assistance in identifying oils of good "cracking" characteristics. The figures for volatility mean little or nothing in themselves, but when studied in parallel with figures for gravity and other physical constants they tell something about the origin of the product in question, and thereby give an indication as to how it will break up in the cracking retorts.

There is one special type of product falling in the gas oil class for which volatility is a property of direct importance. Gas-absorbent oils for natural or manufactured gas, must have initial boiling points well above the final boiling points of the products which are to be absorbed. The distillation test is sometimes used to determine this important property of absorbent oil, although it happens that the open-cup flash or fire test serves almost as well and has the advantage of greater convenience and simplicity.

Crude Oil and Partially Refined Stocks.—The distillation test as applied to crude oil and partially finished stocks, such as crude naphtha, is generally made for the purpose of estimating what yield an quality of some specific finished product can be obtained.

VAPOR PRESSURE AND EVAPORATION TESTS

Vapor Pressure

The vapor pressure of a substance is a measure of its tendency to vaporize and is expressed in units of pressure, for example, pounds per square inch. Vapor pressure increases with temperature, and the temperature at which the vapor pressure of a liquid equals atmospheric pressure is the normal boiling point of the liquid.

Various methods have been developed and described for the approximate measurement of the vapor pressure of volatile petroleum products, such as natural gasoline and motor gasoline, at temperatures both above and below the initial boiling points of the products, but none of these methods has come into general use nor has the procedure been thoroughly standardized.

The so-called vapor pressure test of the Bureau of Explosives[1] is an empirical method and does not measure true vapor pressure. This method has come into general use in this country for classifying petroleum products for transportation by rail, and inasmuch as the results obtained by its use are generally satisfactory for the purpose for which they are obtained and have come to have definite trade significance, there is little likelihood of a change to any other method.

Spot Test

One of the tests frequently specified for the examination of volatile petroleum products, used as paint and varnish thinners, is the so-called "spot test." This test appears in various forms and modifications, of which the best known is probably Method 120.11, appearing on page 64 of Bureau of Mines *Technical Paper No. 323A*.

The test is supposed to be a simple, rapid and delicate method of determining whether a product is free from constituents that do not evaporate readily. Actually, it seems to be a very unsatisfactory and unscientific substitute for a properly interpreted distillation test. The "Spot Test" could possibly be developed and modified into a reproducible quantitative method, but an attempt to do this would rob it of simplicity which is its chief claim for merit. It is usually necessary to make a distillation on products for which the "Spot Test" is employed, and if this is done the latter becomes superfluous.

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[1] Manufacturers Circular Letter, No. 147.

Evaporation Test

Specifications for lubricating oils occasionally include a requirement of the following general type:

"The oil when heated for .... hours at a temperature of .... shall not lose more than .... per cent."

There are numerous modifications of this clause and details of the working procedure are almost always omitted. The results are likely to be quite variable even if details are specified. Flash and fire point tests provide adequate information regarding the tendency of a lubricating oil to evaporate and there seems to be no justification for continuing the use of so-called evaporation test.

TESTS FOR ILLUMINATING OILS

Introduction:

The group of petroleum products classed as illuminating oils comprises the products which are burned in wick burners for the production of light or heat. The term kerosine is sometimes regarded as synonymous for illuminating oil, but certain grades of kerosine sold for use in internal combustion engines and for vaporizing or atomizing burners cannot be classed as illuminating oil. The term illuminating oil also includes products which cannot be designated as kerosine.

The essential property of illuminating oil is that it shall burn satisfactorily in a wick burner. Ordinary kerosine is used in many types of equipment, including both lamps and heaters, and must be of a quality suitable for all the equipment in which it is likely to be used. Special grades of kerosine are required for uses which involve burning for relatively long periods without attention. In this class are the so-called long-time burning oils used in railroad semaphore lamps, and the incubator oils.

There are also a number of minor uses for illuminating oil of high flash point, for example, in lamps used in railway coaches, and for this service a product known variously as 300 Oil or Mineral Seal Oil is employed. Another illuminating oil is the so-called railroad signal oil which is used in hand lanterns and which must possess the property of burning with a flame so strong and steady that it cannot be extinguished by the necessary swinging of the lanterns.

The only conclusive method for determining the quality of an illuminating oil is to make a burning test in the equipment in which it is to be used. This is not generally practicable, and the next best procedure is to test it in certain selected types of equipment that are known to be more severe in their requirements of quality than the average equipment likely to be encountered in actual use. There are also a number of physical and chemical tests which are intended to indicate burning quality of illuminating oil, but these are of chief importance to the refiner who desires to ascertain what particular property is responsible for the failure of a product to give a satisfactory burning test.

Scope of Methods:

Burning Test for Kerosine.—The A.S.T.M. Standard Method of Test D 187 - 27[1] is applicable to kerosine which is used in ordinary types of wick burners, such as household lamps, oil heaters and oil cookstoves. The test burner is of the flat wick type and is of more or less obsolete design, especially selected to magnify defects in quality which might not be observed if the oil were used in the improved types of burners now generally available.

Burning Test for Long-Time Burning Oil.—The A.S.T.M. Standard Method of Test D 219 - 27[2] is applicable to kerosine to be used in railway semaphore lamps and in other wick burners, which due to their design or method of use require very highly refined oil.

Burning Test for Mineral Seal Oil.—The A.S.T.M. Standard Method of Test D 239 - 27[3] is intended for the determination of the burning quality of the special illuminating oil known to the trade as Mineral Seal Oil or 300 Oil and involves the use of a standard type of burner used in railway coach lamps.

Burning Test for Signal Oil.—The A.S.T.M. has not standardized a method for testing signal oils, but one which has been described in print is Method 210.5 appearing on page 64 of Bureau of Mines *Technical Paper No. 323.* This method is not specific with regard to equipment or details of procedure and cannot be regarded as a standard method.

Distillation Test for Kerosine.—The A.S.T.M. Standard Method of Test D 86 - 27 is applicable to kerosine but not to 300 Oil or Signal Oil.[4]

Sulfur Determination.—The A.S.T.M. Tentative Method of Test D 90 - 26 T is applicable to all types of illuminating oil.[5]

Viscosity Test for Kerosine.—The Society has not standardized a method for determining the viscosity of kerosine. The Saybolt Thermo-Viscometer and the Ubbelohde Viscosimeter are commercial instruments suitable for testing kerosine.[6]

Flock Test for Kerosine.—The so-called flock test, which indicates the presence of certain inorganic impurities, has not been standardized by the Society, but is described in Bureau of Mines *Technical Paper No. 323B*, page 68 (Methods 130.1 and 130.2) and is applicable to kerosine and 300 Oil.

Significance of Results:

Burning tests of illuminating oils are essentially performance tests, and represent a direct method of determining the quality of the oils for the purposes intended. It is, of course, impossible to make such tests in all kinds of commercial equipment, or under all possible conditions (including location, time, temperature, air currents and cleanliness). These difficulties are overcome, in part at least, by the selection of burning test equipment known to be severe on the oil and by extending the test beyond the average time interval between cleanings in the ordinary use of the lamp.

None of the burning test methods mentioned above, or for that matter none that has ever been devised, gives results that can be reported adequately in numerical terms. Their real usefulness lies in the fact that they prescribe efficient procedure for comparing the quality of different samples or grades of oil, particularly with respect to details of behavior. The subject of interpreting results of burning tests cannot be discussed adequately in writing, and, as a matter of fact, there is no substitute for actual experience. It is relatively easy to tell a very good from a very bad oil, but this question rarely comes up; the usual need is for information as to whether an oil is slightly better or worse than standard, and to supply this information, it is necessary to rely on the observations of a skilled operator and to interpret them in terms of what is known of the service requirements of the product.

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 364.

[2] *Ibid.*, p. 370.

[3] *Ibid.*, p. 374.

[4] See p. 497.

[5] See p. 513.

[6] See p. 486.

The theoretically perfect illuminating oil is one that would burn for an infinite period of time without change in the shape and size of the flame, without change in wick, without fouling any part of the burning equipment, and without the production of odorous products of combustion. This ideal, of course, has never been attained, and the market products which come nearest to it are so costly to produce and so limited in quantity that they cannot be used as normal standards of quality. The practical requirement is oil which will give the results that the user expects, and this puts the question of observations and interpretation flatly on the basis of experience and judgment of the tester. About all that can be done in the present connection is to discuss briefly the observations that are of importance and the deficiencies in quality that may be encountered.

The most important features are shape and size of the flame. Oils are occasionally encountered which have a viscosity so low that flame size increases, or so high that it decreases, during the period of burning. Generally, however, changes in flame size or shape are due to changes in that portion of the wick which feeds the flame. An incrustation always forms on the wick, and is not objectionable unless it affects the flame. Some types of wick crust are "bushy" and increase flame size; others tend to enclose the surface of the wick and cause flame shrinkage. The worst feature, however, is an irregular deposit, sometimes localized through the formation of mushrooms ("ears," "niggers," "toadstools") which produces distortion. A distorted flame usually generates smoke which, from the point of view of the user, is the worst thing that can happen.

The condition of the chimney at the end of the test is important. Satisfactory oil should not cloud or smoke the chimney, thereby obscuring the light. A black sooty deposit is obviously highly objectionable, but the tester must always assure himself that it is not due to drafts or to improper testing. A heavy whitish deposit nearly always forms when a new chimney is put into service, and the condition of the chimney should always be interpreted with this in mind.

While burning tests on illuminating oils cannot be made without experience and strict attention to detail, and while the judgment of the operator plays a greater part in the interpretation of the tests than for most tests of other petroleum products, the fact remains that they furnish the only reliable means for the ultimate estimation of the quality of illuminating oils.

The distillation test, the flock test, and the viscosity test are of value only to the refiner, as a means of determining why a given oil fails to perform properly in burning test equipment. The distillation and viscosity tests, taken alone, are of little use in evaluating an illuminating oil, and are of significance only when their results are considered in connection with other known characteristics of the oil. They will tell the consumer nothing that the more direct burning tests will not tell, and their use in specifications is of questionable value.

The sulfur determination is a means of giving quantitative expression to the amount of sulfur dioxide which is likely to be liberated when the oil is burned in closed rooms. For this reason it is of considerable value in supplementing the burning test on kerosine for household use. For long-time burning oil, or other illuminating oil to be burned out of doors, the sulfur content is of no direct importance, its indirect effect being adequately covered by the Lamp Burning Test.

The flock test, which was formerly considered to be of great importance as an indicator of proper refining, has lost most of its significance in recent years. It tells nothing that a burning test will not also reveal, and its inclusion in a specification is an entirely unnecessary complication.

WICK FEED TEST

Reciprocating steam engines for marine service are lubricated by oil passing through wool wicks to moving parts and it is necessary that the oil contain no impurities that would clog the wicks. The Society has not standardized a procedure for measuring this quality.

A method that may be employed is described in Bureau of Mines *Technical Paper No. 323-B*, page 69. The test requires fourteen days. It involves measuring the quantity of oil lifted by the force of capillarity through a specially prepared wool wick. Observations are made at the expiration of 24 hours, 48 hours and 14 days. This test simulates conditions of service, and interpretation is based on comparison with results obtained on oils known to be satisfactory for this type of lubrication.

WATER AND SEDIMENT

The determination of water and insoluble solid impurities is one of the most important tests made on crude petroleum and some of its products. The methods employed are simple in principle but in some cases involve empirical features. The three most important laboratory test methods are the centrifugal method for both water and sediment, the distillation method for water, and the extraction method for sediment.

Water and sediment by centrifuge, frequently designated as "B.S. and Water," is the percentage by volume of the aqueous layer, including sediment and incompletely broken emulsion, separated when the oil under test is centrifuged under specified conditions.

Water by distillation is the volume of water as determined by a distillation test made according to correct procedure. This determination is practically independent of empirical factors and the procedure which is frequently prescribed represents the most convenient but not the only accurate method of making the test.

Sediment by extraction is the percentage by weight of insoluble material which exists in particles of sufficient size to be retained by a porous filter of specified characteristics. This method is, of course, highly empirical.

Scope of Methods:

Water and Sediment by Centrifuge.—The A.S.T.M. Standard Method of Test for Water and Sediment in Petroleum Products, by Means of Centrifuge (D 96 - 28)[1] is the most desirable of the various methods of its type. It involves diluting the oil to be tested with benzol and centrifuging under specified conditions. This method is convenient and ordinarily yields closely reproducible results, but is, nevertheless, empirical. Its chief disadvantage is that, when applied to oils of too high viscosity, it may not effect complete separation of the water and suspended solids.

Other centrifugal methods, not standardized by the Society, involve the use of petroleum naphtha and carbon disulfide as diluents. In some cases these diluents are highly unsuitable and in no case are they preferable to benzol.

Water by Distillation.—The A.S.T.M. Standard Method of Test for Water in Petroleum Products and Other Bituminous Materials (D 95 - 28)[2] is a convenient and accurate procedure for determining the water content of all oils. It involves distilling a measured quantity of oil, mixed with a specified diluent, and collecting the distillate in a graduated receiver, so designed and attached as to permit the excess of the non-aqueous layer of the distillate to return continuously to the distilling flask or retort. The one serious limitation of the distillation method is that it determines water only and not sediment and water.

Sediment by Extraction.—No method of the determination of sediment has been standardized by the Society, but Method 300.2, page 78, Bureau of Mines *Technical Paper No. 323B*, outlines a procedure which is rather generally employed for testing the heavier grades of fuel oil. This method determines gravimetrically the sediment insoluble in benzol, which is in the form of particles sufficiently coarse to be held by a porous filter of specified characteristics. The method has many undesirable features and a sub-committee of Committee D-2 is now actively engaged in an attempt to provide a more suitable test.

Other Methods for Water and Sediment.—None of the qualitative methods for determining the presence of water and sediment in oil has been standardized but those of chief importance are so obvious that this is unnecessary. In products which are normally transparent, the presence of water or sediment is determined by visual examination of a sample, in a transparent container. Water may be observed either as a continuous layer, as drops, or, if finely dispersed, as a cloud or haze. With electric insulating oils the so-called breakdown voltage test indicates the presence not only of traces of dissolved water but of other impurities which conduct electric current. The presence of more than traces of moisture in non-transparent lubricating oils is evidenced by characteristic frothing upon heating or during the course of the flash test.

A gravity settling test is sometimes employed for the estimation of "B.S. and Water." Tests of this type, if properly standardized, yield reproducible results with certain of the less viscous oils but are not desirable except when the laboratory facilities do not permit the use of a centrifuge.

There is no standard method for determining the ash content of oil, but, as empirical factors are not involved, a definitely prescribed procedure is unnecessary. All that is essential is to burn a weighed quantity of oil, ignite, and weigh the ash. The one major precaution is to avoid mechanical losses during the processes of burning and final ignition.

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[1] 1928 Supplement to Book of A.S.T.M. Standards, p. 152.

[2] *Ibid.*, p. 148.

Significance of Results:

For fully refined petroleum products it is customary and practical to specify freedom from water and sediment, as indicated by the transparency and "bright" appearance of a 4-oz. sample. Certain of the heavier lubricating oils are likely to contain a trace of water and it is customary to rely upon the behavior of the oil during the flash test as an indication of this. If an excessive amount of water is indicated, it may be determined quantitatively, preferably by a modification of the standard distillation method, using a test portion sufficiently large to yield at least 0.2 cc. of water.

Crude petroleum and semi-refined products, such as fuel oil and gas oil frequently contain measurable quantities of water and sediment and are usually subjected to quantitative tests for one or both of these impurities. The A.S.T.M. centrifuge test is generally employed for gas oil and for all but the heavier and more viscous fuel oils and crude oils. The results obtained are admittedly less accurate than those obtainable by the distillation method, but the agreement between check tests is satisfactory.

Crude oils and fuel oils of high viscosity should be tested for water by the distillation method. Crude oils generally do not contain sufficient quantities of sediment to render the use of the extraction method necessary, and as a matter of fact a determination of ash content is preferable, since sediment present in crude oil is normally inorganic material, such as sand, silt or iron rust.

PRECIPITATION TESTS

Crude petroleum contains constituents which for want of a more definite description are classed as "asphalt." These constituents are non-volatile and by distillation are concentrated in the residual products. If the latter are to be used as lubricants, it is frequently necessary to test for the content of asphaltic material.

The chemical composition of this material is not known, but it is sparingly soluble in naphtha composed of low-boiling paraffin hydrocarbons, and this characteristic is the basis of the various so-called precipitation tests.

Scope of Methods:

The A.S.T.M. Tentative Method of Test for Precipitation Number of Lubricating Oils (D 91 - 21 T)[1] involves diluting the oil to be tested with petroleum naphtha of specified properties, and separating the precipitate by centrifuging. The volume of the separated layer is reported as the A.S.T.M. Precipitation Number of the oil.

This test is not entirely satisfactory as the present specification for the diluting naphtha does not insure the necessary degree of uniformity of solvent power, but a new specification is in process of development by the committee. Another disadvantage is that the compactness of the precipitate is not the same for all types of oil, from which it follows that no definite relation exists between A.S.T.M. precipitation numbers and percentages of "asphalt" as determined by gravimetric methods. The advantages of the method are that it is simple and convenient, and avoids laboratory operations which call for chemical training on the part of the operator.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 21, p. 648 (1921); also 1928 Book of A.S.T.M. Tentative Standards, p. 440.

The so-called Holde "hard asphalt" method[1] involves dissolving a weighed quantity of oil in a specified grade of naphtha (so-called normal benzine), allowing the mixture to stand 24 hours, filtering off the precipitated material and weighing the latter. This method is largely used in Europe, and to a certain extent in this country. It is reasonably satisfactory as regards reproducibility of results and is not subject to the objections which apply to volumetric methods, but is time-consuming and involves skillful operating technique. It has the additional disadvantage of involving the use of a "certified" diluting naphtha obtainable from only one source of supply and which is not adequately distributed.

There are other methods for determining "asphalt" in oil, but the general principles involved are similar to those of one or other of the two methods described above. The variations in details of procedure, however, are reflected in the results obtained, and it is necessary to specify the method whenever the "asphalt" content of an oil is reported.

Significance of Results:

The effect of "asphalt" content upon the lubricating qualities of an oil is not definitely known. For certain types of service there is no question as to the unsuitability of oils which contain appreciable quantities of asphaltic constituents, but on the other hand the importance of moderate variations undoubtedly is exaggerated by many users. The chief value of precipitation tests is in classifying the several groups of residual lubricating oils. Filtered products, such as the so-called "bright stocks" largely used as constituents of motor oils, contain negligible quantities of asphalt. Another group, which includes steam-refined cylinder stocks, is characterized by a moderate percentage of material that is insoluble in "light" naphtha. So-called black oils, which are used for such purposes as the lubrication of gears and car journals, usually show precipitation tests that are moderately high.

EMULSIFICATION

When oil and water are mixed in any manner they generally tend to separate more or less rapidly on standing. The presence of small amounts of certain other materials decreases the rate of separation and may prevent any separation whatever. This physical condition is known as an emulsion, and the phenomenon is known as emulsification.

For certain purposes, as, for example, in the lubrication of marine engines and in the lubrication and cooling of certain types of metal-cutting tools, it is desirable that the oil form a relatively stable emulsion with water. For other purposes, particularly in the lubrication of steam turbines, it is highly essential that any emulsion which may be formed separate rapidly and completely Accordingly a knowledge of the rapidity with which the constituents of an emulsion of oil and water will separate is of considerable value. Since it is not possible to duplicate service conditions in the laboratory, it is necessary to measure the rapidity of separation under some arbitrarily selected set of conditions. This is expressed in some numerical form which serves as an index of the emulsifying characteristics of the oil.

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[1] D. Holde, "Kohlenwasserstoff und Fette," Sechste Auflage, Berlin, pp. 106–107 (1924).

Scope of Methods:

The A.S.T.M. Standard Method of Test for Steam Emulsion of Lubricating Oils (D 157 - 28)[1] is designed for use on oils whenever a knowledge of the tendency to separate from water is required. It is particularly applicable to turbine oils. Steam is passed into the oil under specified conditions and the time in seconds required for complete separation of the oil and condensed steam is recorded as the Steam Emulsion Number (S.E. Number) of the oil.

Another procedure is Method 320.31 for Demulsibility at 130° F. given on page 85 of U. S. Bureau of Mines *Technical Paper No. 323B.* Oil is paddled with water under specified conditions and the maximum rate of separation of the oil, in cubic centimeters per hour, is recorded as the Demulsibility. Method 320.41 is a modification of the procedure with respect to temperature of test. Methods 320.11 and 320.21 for Emulsion Test at 130° F. and 180° F., respectively, make use of the same apparatus, but use sodium hydroxide solution and salt solution in addition to water, and the separation is recorded as being complete or incomplete after 30 minutes standing.

Significance of Results:

For forced-feed circulating lubrication systems where the oil is likely to come in contact with water or steam, the steam emulsion test is of great importance. This is particularly true of steam-turbine lubricating systems. For oils intended for this type of service the use of a test of this kind is thoroughly established. Next to viscosity it is considered the most important test for steam turbine oils, since rapid separation from water is an essential characteristic.

For certain types of marine engine lubrication the opposite is the case. Here it is desired to secure an oil which will separate from water very slowly and the persistence of the emulsion is a matter of prime importance. This is also true of oils used for lubricating and cooling certain types of cutting tools.

For oils intended for other purposes the use of the test is of debatable value. While the test is sometimes included in specifications for such oils, there is no uniformity of opinion as to its practical value, and, in general, it may be considered unncessary.

OXIDATION AT HIGH TEMPERATURES

When petroleum oils deteriorate in service, this deterioration is generally accompanied by oxidation and the formation of oxidation products. In some types of service the possibility of oxidation is not considerable, but in others, for example the lubrication of steam turbines and the insulation and cooling of transformers, the ability of the oil to resist chemical change is of prime importance. Accordingly a method of test that will measure this characteristic is desirable.

For different classes of service, different types of tests have been proposed, all of the accelerated type. Some of the methods have been developed to such a degree that the results obtainable are moderately reproducible, while others have not even reached the stage of yielding concordant results in the hands of a single operator. None of these methods, whether good or poor from the point of view of laboratory technique, has been correlated with service behavior to such degree as to make possible any agreement as to which tests should be standardized for universal use.

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[1] 1928 Supplement to Book of A.S.T.M. Standards, p. 143.

DIELECTRIC STRENGTH

When a material that may be classed as a non-conductor of electricity is subjected to an electric potential, only a negligible current flows until the electrical stresses have reached an intensity at which there is a sudden and large increase in current and an electrical and mechanical breakdown occurs. The value up to which the electrical stress must be brought in order to cause the electrical breakdown is called the dielectric strength of the material. This is expressed as voltage per unit length and is stated in kilovolts per millimeter or in equivalent units. In test methods where a single definite break-down distance has been standardized upon, the term "dielectric strength" is often applied simply to the voltage at which break-down occurs.

Scope of Methods:

The A.S.T.M. Standard Methods of Testing Electrical Insulating Oils (D 117 - 27)[1] include a procedure for the determination of the dielectric strength of oils used in transformers, oil circuit breakers, and other electrical apparatus as an insulating or cooling medium, or both. The test involves subjecting the oil to a gradually increasing electrical stress in a test cup fitted with fixed-gap electrodes consisting of circular disks of polished brass or copper.

The A.S.T.M. Tentative Methods of Testing Cable Splicing and Pothead Compounds (D 176 - 25 T)[2] include a procedure for the determination of the dielectric strength of semi-solid and solid compounds used in cable splices and potheads. The test involves melting the sample, pouring it into the test container, and applying the electrical stresses at several different temperatures.

Significance of Results:

Dielectric strength, when reported simply as the number of kilovolts, is without significance, unless the shape and size of the electrodes, spacing, frequency and wave form of voltage, and rate of voltage application are specified or understood. Temperature and other physical conditions also affect the experimental values. Fixed-gap methods, such as those mentioned above, are particularly suited to the testing of insulating liquids and insulating materials that can be readily melted, as their use renders unnecessary separate measurement and report of the gap length in each test, and eliminates variations in stress due to changes in shape of electrodes, and other factors.

The "dielectric strength," as determined by these methods, may be taken as a measure of the adequacy of insulating materials for the electrical stresses they are intended to resist. This test may be used in measuring the effect of contamination, in new or used materials, by such substances as water, dirt and conducting particles. It is also used by operators of electrical equipment as an indication of aging in service.

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 796.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 25, Part I, p. 810 (1925); also 1928 Book of A.S.T.M. Tentative Standards, p. 635.

CARBON RESIDUE

Petroleum products are mixtures of many compounds which differ widely in their physical and chemical properties. Some oils may be vaporized at atmospheric pressure and in the absence of air without leaving an appreciable residue, while other oils, upon distillation, leave a non-volatile carbonaceous residue. This residue when determined in accordance with prescribed procedure is designated "carbon residue."

Scope of Method:

The A.S.T.M. Standard Method of Test for Carbon Residue of Petroleum Products (Conradson Carbon Residue) (D 189 - 28)[1] involves destructive distillation of a weighed quantity of oil in apparatus so designed as to exclude air, to permit proper control of rate of heating, and to eliminate possible condensation of distillates in or on the oil contained. This method is a modification of the procedure devised by P. H. Conradson and described by him in 1912.

Significance of Results:

The carbon residue test was originally developed for comparison of the carbon-forming properties of lubricating oils for internal combustion engines. It is frequently claimed that the quantity of carbon deposited in cylinders and on pistons is proportional to the carbon residue of the oil. Under ideal conditions this is probably true, but with average operating conditions, other factors, such as the viscosity of the oil, the mechanical condition of the engine and the conditions of carburation of the fuel, may dominate in controlling carbon deposition.

It has been found that the carbon residue content of the oil bears a fairly direct relation to the quantity of carbonaceous residue deposited in the carbureting apparatus. Consequently the carbon residue test has been used for determining the carbon-forming tendency of such petroleum products as gas oil and fuel oil.

In the operation of certain types of oil burning equipment and heavy oil internal combustion engines, the conditions of vaporization and combustion make possible the deposition of a carbonaceous residue, and in such cases, the carbon residue of the oil fuel may be important.

ACIDITY IN GASOLINE

The so-called acidity test, as applied to gasoline, is actually a qualitative test for the presence or absence of free acid or organic compounds of a mineral acid which are decomposed at moderately high temperatures. The only acid which could normally be present in gasoline is sulfuric acid, which is one of the chemicals used in the refining process.

The Society has not standardized this test, but Method 510.2, published in Bureau of Mines *Technical Paper No. 323B*, page 89, describes a procedure which involves extracting the distillation residue with distilled water and testing the extract for acidity with methyl orange indicator.

This test is essentially a refiners' test and a positive indication rarely occurs with products which have been released to the consumer. The presence of free acid is obviously an indication of improper refining.

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[1] 1928 Supplement to Book of A.S.T.M. Standards, p. 129.

NEUTRALIZATION NUMBER

Practically all petroleum lubricating oils contain substances, of varied and indeterminate chemical composition, which have acid characteristics. The proportion of these substances present in an oil is commonly referred to as its "organic acidity." These acid compounds are, mainly, natural constituents of crude petroleum and their presence in finished lubricating oil is not necessarily an indication of improper refining or poor quality.

A large proportion of the petroleum lubricating oils now produced undergo treatment with mineral acid and caustic alkali in the course of refining. If the refining operations are not properly conducted, small quantities of one or the other of these chemicals may remain in the finished oil and, of course, are undesirable and unnecessary impurities.

The "Neutralization Number" of an oil is defined as the weight in milligrams of potassium hydroxide required to neutralize one gram of oil. It represents the sum of the quantities of mineral and so-called organic acids present in the oil or the difference between the organic acidity and the alkali present in the oil. If, as is usually the case, no mineral acid or alkali is present in the oil, the neutralization number is directly proportional to "organic acidity."

The "Alkali Neutralization Number" is defined as the weight in milligrams of potassium hydroxide equivalent to the acid required to neutralize one gram of oil.

The "Mineral Acid Neutralization Number" is defined as the milligrams of potassium hydroxide required to neutralize the mineral acid content in one gram of oil.

In writing specifications for lubricating oils it is more or less common practice to require that the "organic acidity calculated as percentage of oleic acid" or the "organic acidity calculated as SO_3" shall not exceed some selected limit. This involves making unnecessary and useless calculations after obtaining the actual experimental results of the neutralization tests and is also objectionable because there is an implication that the oil in question may contain constituents which are not likely to be present.

Scope of Method:

The A.S.T.M. Tentative Method of Test for Neutralization Number of Petroleum Products and Lubricants (D 188 - 27 T)[1] involves determination of Neutralization Number by titrating with standard alkali the hot alcohol extract of a weighed quantity of oil. The Alkali Neutralization Number or the Mineral Acid Neutralization Number is determined by extracting a weighed quantity of oil with hot distilled water, testing with an indicator to ascertain whether this extract is acid or alkaline and titrating with an appropriate standard solution. If, as is usually the case, the extract is neutral, no titration is necessary and the Alkali and Mineral Acid Neutralization Numbers are zero.

All other tests for neutralization number are based on the same general principle as the A.S.T.M. Method. The differences concern details of operation or the terms in which test results are reported.

Significance of Results:

It is obvious that the effect of alkali or mineral acid in a petroleum oil is deleterious, and it is usual to specify that the Alkali or Mineral Acid Neutralization Number shall be either zero or some extremely low figure. The practical significance of "Organic Acidity" is complicated by many considerations. The essential facts are as follows:

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 927 (1927); also 1928 Book of A.S.T.M. Tentative Standards, p. 431.

1. Oils derived from certain crude oils commonly show low neutralization numbers while oils from other crude oils show relatively high neutralization numbers, unless subjected to special processes.

2. The organic acids normally present in lubricating oil are not corrosive and have no directly harmful effects.

3. It is contended by some, although the supporting evidence is not absolutely definite, that the presence of organic acids improves the friction-reducing qualities of oil.

With these facts in mind, it is evident that the general quality of a lubricating oil cannot be evaluated in terms of its neutralization number. Specifications should never include limits on this property unless it is known that an oil of low organic acidity is required.

TOTAL SULFUR OR SULFUR CONTENT

In commercial testing of petroleum products for sulfur content, it is customary to determine the total amount of sulfur, without attempting to separate this value into quantities representing the various classes of sulfur compounds. The doctor test (see page 80) and corrosion tests (see page 81) give qualitative indications of the presence of certain particular types of compounds.

The quantitative determination of sulfur in petroleum products consists of a complete oxidation of the material, and an analysis of the oxidation products.

Scope of Method:

The A.S.T.M. Standard Method of Test for Sulfur in Petroleum Oils Heavier than Illuminating Oils (D 129 - 27)[1] prescribes oxidation of the material by combustion in a calorimeter bomb containing oxygen under pressure. The oxidation products of the sulfur are dissolved in a small quantity of water contained in the bomb and after a supplementary oxidation with bromine, are analyzed for sulfuric acid by precipitation as barium sulfate. This method is most suitable for the determination of sulfur in petroleum oils heavier than illuminating oil and can be used also for all classes of petroleum oils. For highly volatile materials, special precautions must be taken to prevent evaporation losses during weighing. With careful work, results of duplicate determinations should agree within 2 per cent of the sulfur content in the case of material containing above 1 per cent of sulfur. For material of lower sulfur content, the relatively small amount that can be used for the test lowers the degree of accuracy. Careful work, however, ought to yield duplicate results that do not differ more than 0.01 per cent of the material.

In the Tentative Method of Test for Sulfur in Naphtha and Illuminating Oils (D 90 - 26 T),[2] the oxidation is effected by combustion of the material in a small lamp. The combustion products are passed through a solution of sodium carbonate. The decrease in alkalinity of this solution is proportioned to the quantity of sulfur contained in the oil. This method is applicable to gasoline, naphtha, illuminating oil and light gas oil, providing these materials are free from suspended matter and substances that are retained by the wick. If such substances are present, Method D 129 – 27 should be used. Method D 90 – 26 T permits the combustion of larger quantities of material than can be handled by the bomb method, which tends to increase the degree of accuracy in the case of oils of low sulfur content. The method also requires less time than Method D 129 – 27. The accuracy of this method, as applied to motor fuels containing considerable percentages of benzol, has been questioned, but its unsuitability for use with this material has not been proved.

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 419.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, p. 848 (1926); also 1928 Book of A.S.T.M. Tentative Standards, p. 443.

The Kennedy method[1] employs a small wickless lamp with a heating wire to produce vaporization, and has been developed by the Bureau of Standards as a possible substitute for the small wick lamp in Method D 90 – 26 T. This test is applicable only to volatile materials, such as gasoline and naphtha.

Significance of Results:

The significance of the total sulfur content varies greatly with the product and the uses to which it is put; accordingly, the more important products are considered separately. In general, the total sulfur content is important only when the material is to be burned under conditions which make undesirable the presence of much sulfur dioxide in the products of combustion; otherwise, only the corrosive forms of sulfur are undesirable, and these should preferably be detected by appropriate corrosion tests (see page 81).

Motor Fuels.—While total sulfur (as distinct from corrosive sulfur) has no significance in connection with the induction system of an automobile engine, it may cause trouble, particularly in winter, because a small portion of the products of combustion may find its way into the crankcase and may remain in the cylinders when the engine is stopped. If the fuel contains much sulfur, and if liquid water is present, a dilute solution of sulfurous and sulfuric acids is formed which may cause serious corrosion of parts, such as cylinder walls, bearings and starter chain. This trouble is characteristic only of winter operation in engines which, due either to their design or method of operation, run rather cold and accumulate considerable quantities of water.

Burning Oils.—Any oil which is burned in lamps or stoves indoors should obviously have a fairly low total sulfur content. The presence of considerable quantities of sulfur also appears to injure the burning qualities of an oil in a wick burner (see page 68).

Fuel Oil.—The importance of the total sulfur content of a fuel oil is frequently overestimated. The sulfur compounds are readily combustible, have a high heating value, and in a properly arranged household or industrial furnace, they are neither noticeable nor harmful except in certain metallurgical operations and in a few cases where the use of highly efficient economizers cools the flue gases to temperatures which permit the condensation of water and sulfurous acid on metal surfaces, with resulting corrosion. Most of the lighter or distillate fuel oils contain less sulfur per unit heating value than does coal.

Lubricating Oils.—The total sulfur content of ordinary lubricating oils is of no known significance. The quantity of oil actually burned in an automobile engine seldom exceeds 1 per cent of the quantity of gasoline burned, and therefore its products of combustion can have no appreciable effect on crank case corrosion. In thread-cutting oils a high content of sulfur is sometimes considered desirable in the belief that it makes possible more rapid cutting and smoother work.

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[1] H. T. Kennedy, *Industrial and Engineering Chemistry*, Vol. 20, p. 201 (1928).

Other Products.—As indicated above, the importance of the total sulfur content of petroleum products depends largely on whether they are burned in service and on how the products of combustion are handled. Sulfur dioxide itself is not a corrosive agent except when dissolved in water, and the temperatures in flue gas systems are seldom low enough to permit this. The importance of the sulfur content of any product can be estimated only after careful consideration of the conditions of use.

DOCTOR TEST

The doctor test[1] is essentially a very sensitive chemical test for hydrogen sulfide and mercaptans. The test is made by shaking the product to be tested with a solution of sodium plumbite made by dissolving litharge in caustic soda. After shaking vigorously, a pinch of sulfur is added and the mixture is shaken again. If the sample is discolored or if the yellow color of the sulfur film is noticeably masked, the sample is generally reported as "sour"; but if it remains unchanged in color and the sulfur film is bright yellow or only very slightly discolored with gray or flecked with black, the sample is reported as "sweet."

If much hydrogen sulfide is present, a black precipitate is formed before the sulfur is added and will generally mask any mercaptan precipitate. If mercaptans are present, with little or no hydrogen sulfide, the first precipitate will be yellow or orange in color and will darken slowly after the sulfur is added, eventually becoming black. The chemical reactions involved in the case of mercaptans are essentially as follows:

$$\begin{array}{ccccccc} 2\,\mathrm{RSH} & + & \mathrm{Na_2PbO_2} & = & \mathrm{Pb(RS)_2} & + & \mathrm{2NaOH} \\ \text{a mercaptan} & + & \text{sodium plumbite} & = & \text{lead mercaptide} & + & \text{sodium hydroxide} \\ & & & & \text{(orange)} & & \end{array}$$

$$\begin{array}{ccccccc} \mathrm{(RS)_2Pb} & + & \mathrm{S} & = & \mathrm{PbS} & + & \mathrm{(RS)_2} \\ \text{Lead mercaptide} & + & \text{sulfur} & = & \text{lead sulfide} & + & \text{a disulfide} \\ \text{(orange)} & & & & \text{(black)} & & \text{(oil soluble)} \end{array}$$

In the case of heavier products such as kerosine, the lead mercaptides may be sufficiently soluble to give a yellow or orange tinge to the oil layer instead of forming a precipitate with the doctor solution. On the addition of sulfur the oil layer will darken slowly and will give eventually a dark precipitate.

Scope of Method:

The test is applicable to the group of products comprising naphthas and kerosine.

Significance of Test Results:

Contrary to a belief frequently held, the doctor test gives no indication of the total quantity of sulfur in an oil. It also fails to indicate the presence of free sulfur, which is the usual corrosive agent in gasoline. It does indicate the presence of mercaptans, which in general are not corrosive. For the detection of corrosive sulfur compounds it is decidedly inferior to the copper strip test. While the doctor test is the best available test for mercaptans, it is debatable whether these compounds are harmful in the low concentration normally existing in the majority of refined products. Higher concentrations would, of course, give a characteristic odor to the product and might be considered undesirable for this reason. The determination of the total sulfur content, together with suitable qualitative tests for corrosive sulfur compounds, is generally believed to give a better indication of the quality of a product, so far as its sulfur content is concerned, than does the doctor test.

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[1] **This test is described in Bureau of Mines *Technical Paper No. 323B*, page 96. It has not been standardized by the Society.**

CORROSION TESTS

Petroleum products are frequently used in contact with metal, and when it is essential that the metal shall not be corroded, it is customary to require that the petroleum products pass an appropriate corrosion test. The corrosive substance most likely to be present in such products as gasoline and kerosine is free sulfur which attacks copper readily. It is, therefore, customary to require that products of this type shall pass a test involving contact with polished copper for a specified period of time, at a specified temperature. For certain other products, which (if imperfectly refined) may contain corrosive free acids, tests are sometimes made which involve determining the effect upon iron or steel as well as copper.

Products such as slushing oils and greases, which are used to protect metal surfaces from corrosion, are generally required to pass special tests, differing in principle from those mentioned above. These tests measure the degree of protection afforded by the product under specified conditions, such as a salt spray or immersion in water, and should not be confused with tests which measure the corrosive properties of the product itself (see page 82).

Scope of Methods:

The A.S.T.M. Tentative Method of Test for Detection of Free Sulfur and Corrosive Sulfur Compounds in Gasoline (D 130 - 27 T)[1] involves determination of the discoloration produced when a strip of sheet copper is immersed in the gasoline for three hours at a temperature of 122° F. (50° C.). This method is applicable, also, to kerosine and to other "white" products. This test is one which can be made conveniently and which yields reproducible results, its one serious drawback being that it does not include any quantitative means of measuring the "extremely slight discoloration" which is the limit that differentiates products which pass and which do not pass.

A similar method, involving a temperature of 212° F. (100° C.) and a test period of three hours, has been adopted by the U. S. Government for determining the corrosive properties of lubricating oil. The official procedure is published as Method 530.31 Bureau of Mines *Technical Paper No. 323B*, page 97. This method is obviously more severe than the A.S.T.M. test described above and, in any event, is not suitable for volatile products.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 926 (1927); also 1928 Book of A.S.T.M. Tentative Standards, p. 412.

U. S. Government Method 530.1, published in Bureau of Mines *Technical Paper No. 323B*, page 96, involves evaporating 100 cc. of gasoline to dryness in a polished copper dish. This test is intended to show both the gum-forming tendency and the corrosive quality of the gasoline. It is only moderately satisfactory when applied to very volatile products, such as aviation gasoline, and is hopelessly variable when applied to motor gasoline.

The A.S.T.M. Tentative Specifications for Petroleum Spirits (Mineral Spirits) (D 235 - 26 T)[1] include a test method for "blackening," which is essentially a high temperature corrosion test. It involves placing a copper strip in the product to be tested and boiling the latter gently for 30 minutes.

Significance of Results:

The A.S.T.M. corrosion test for gasoline is intended primarily as a safeguard against the use of motor fuels which may attack the metal in the fuel and induction systems of internal combustion engines. The test has been in wide use for a number of years and with the exception of its lack of a quantitative standard of interpretation is very satisfactory. It is sufficiently severe to afford the degree of protection required by the user and at the same time does not impose an unnecessary burden of expense by requiring special refinery processing.

The Government corrosion test at 212° F. for lubricating oils is not so widely used as the gasoline corrosion test but seems to afford the proper degree of protection to the user without imposing an unnecessary hardship on the manufacturer.

The copper dish test is one which should never be specified for motor gasoline and one which is of doubtful value for aviation gasoline, so far as indications of corrosive quality are concerned. The test is admittedly more severe than the standard copper strip test but there are so many variable factors involved that it is thoroughly undesirable. The fact that the indications of the test are affected by variations in the atmosphere of the laboratory is sufficient to condemn it.

The boiling test for petroleum spirits is very severe and has the disadvantage of being an index of the sum of two properties. Blackening of the strip may indicate that the product contains corrosive constituents, or constituents which decompose and become corrosive at the temperature involved, or both. The test has been adopted by the Society simply because it is the most practical of several which are available and it is generally recognized that it should be replaced when a better test has been developed.

PROTECTION TEST

Certain petroleum products are used as coatings on metals as protection against corrosion. As both the conditions of exposure and the natural resistance of the metal may vary widely, no protection test has been developed which is applicable to all conditions.

The Society has not standardized a procedure for measuring the protective quality of petroleum products. Method 400.1, Bureau of Mines *Technical*

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, p. 793 (1926); also 1928 Book of A.S.T.M. Tentative Standards, p. 320.

Paper No. 323B describes a procedure which is typical of the general class of protection tests. This test involves immersing a polished steel plate, covered with the material to be tested, in a 10-per-cent salt solution for thirty days, and observing the result.

Such tests are essentially qualitative and their interpretation depends largely upon the judgment of the observer.

SAPONIFICATION NUMBER

The *saponification number* of a fatty or a compounded oil is the number of milligrams of potassium hydroxide required to saponify one gram of the oil. It is a measure of both free and combined fatty acids. If it is desired to determine the amount of potassium hydroxide corresponding to the combined acids, it is necessary to subtract from the saponification number the amount of potassium hydroxide required to neutralize the free acids originally present in one gram of oil.

Saponification numbers of the more common commercial fats and fatty oils fall within the ranges shown in the following tabulation:

FATS OR FATTY OILS	SAPONIFICATION NUMBER
Lard Oil	192 – 198
Tallow	193 – 198
Neat's Foot Oil	193 – 204
Fish Oil	140 – 193
Sperm Oil	120 – 140
Castor Oil	176 – 187
Rapeseed Oil	170 – 179
Soya Bean Oil	189 – 197
Peanut Oil	186 – 197
Cottonseed Oil	191 – 197
Blown Rapeseed Oil	195 – 216
Blown Cottonseed Oil	210 – 225
Degras	110 – 210

Unless the saponification number of the fat or fatty oil is known, it is customary in commercial practice to use a value of 195.

Scope of Method:

The A.S.T.M. Standard Method of Test for Saponification Number (D 94 – 28)[1] presents standardized procedure for this determination and is applicable to any fat, fatty oil or compounded oil. Many procedures for determining this value are described in the literature and practically all of them will, if intelligently carried out, give substantially the same values.

Significance of Results:

The saponification number is the best obtainable index of the percentage of fat or fatty oil in a given product.

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[1] 1928 Supplement to Book of **A.S.T.M. Standards, p. 140.**

ANALYSIS OF GREASE

The majority of lubricating greases are mixtures of petroleum oil and some kind of soap. They may contain, in addition, one or more of such materials as water, fillers, free alkali and organic acids. The quality and the utility of greases are determined chiefly by physical properties; for most of which satisfactory methods of measurement are not at present available. Greases which are satisfactory for given purposes can sometimes be identified by an analysis which separates and identifies their major constituents, and the Society has developed a comprehensive general method for this purpose.

Scope of Methods:

The A.S.T.M. Standard Method of Analysis of Grease (D 128 – 27)[1] prescribes two general systems of procedure. One of these is suitable for light-colored greases, including fiber or sponge greases, axle greases, dripless oils, cutting compounds and solidified oils, and may be applied to soluble cutting oils excepting those containing sulfonated fats. Certain dark greases can also be analyzed by this procedure provided their content of asphaltic material is small. The other procedure is intended for any black greases which, on account of their high "asphalt" content, give troublesome emulsions if the first procedure is used. The first procedure is simpler and is preferable whenever it can be applied.

The method represents a carefully selected and conveniently arranged combination of established analytical operations which include extractions with selective solvents followed by physical and chemical tests to determine the quantity and nature of the major constituents. The kinds of oils or fats used in making the soaps present in the grease cannot ordinarily be determined by the method.

Significance of Results:

From a practical standpoint the most important properties of a grease are physical and include suitable consistency and texture, proper heat resistance for a given purpose, stability in storage, freedom from corrosive action and satisfactory film-forming and friction-reducing properties. None of these properties can be evaluated by analytical methods alone. Consistency, within certain limits, may be determined satisfactorily by A.S.T.M. Method D 217 – 27 (see page 54). This property is dependent to a fairly large extent on soap percentage, but varies also with the temperature of pouring and the rate of cooling of the grease, and other non-chemical factors. Heat resistance is in some degree a function of melting point, which in turn is dependent on the kind and quantity of soap present. Corrosion can be studied by noting the actual effect of the grease on polished metal strips. Stability during storage depends partly on the choice of ingredients and partly on proper manufacture, neither of which can be checked accurately by analytical methods. Film-forming and friction-reducing characteristics, which are the most important items of quality, are obviously outside the scope of any scheme of chemical examination.

Texture refers to the structure of the grease, such as smooth, fibrous, spongy, or rubbery. It is influenced by the basic constituent of the soap, ordinarily sodium or calcium, but does not depend on the quantity of soap present.

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 355.

Fillers include solid substances in finely divided form dispersed in the grease, and insoluble in it. Some must be regarded as adulterants, added to increase weight. Others have definite value as lubricants, or increase cushioning power and reduce noise. The purpose for which a lubricant is manufactured must be considered before the presence of filler is condemned or approved.

Small quantities of water are present in most types of greases and affect the consistency and appearance of the product.

The method of analysis determines satisfactorily the kind of basic (metallic) constituent of the soap, its approximate quantity, the quantity of water, total fillers and petroleum oils. It does not, however, furnish reliable indications as to the character of the fats, fatty oils, or fatty acids used in making the soap, or the exact character of the petroleum oil employed. The results of an analysis do not, of course, indicate the quality or degree of refinement of the various constituents used in making the grease.

The analysis of a mixture as complex as grease requires careful technique and considerable experience on the part of the operator, and at best the results are not nearly so accurate as for inorganic materials. The interpretation of the results of an analysis in terms of probable behavior in service is even more difficult. Two greases showing practically identical analytical results may show marked variations in lubricating performance and keeping qualities.

The method of analysis is more useful to the manufacturer than to the user. Its chief value is to show that a grease is of the general type specified, and that the variations between different lots of the same grade and brand are not greater than are reasonable. Purchase specifications which include close numerical limits, based on an analysis of a particular grease, are unfair to the manufacturer and do not insure giving the consumer what he needs.

REPORT OF COMMITTEE D-4
ON
ROAD AND PAVING MATERIALS

Committee D-4 has held three meetings during the past year. One new method of test and one new recommended practice are offered this year, five existing tentative specifications and methods of tests have been revised and one tentative method of test is recommended for advancement to standard.

A considerable amount of work has been done in the development of specifications for concrete pavements and bases and while the committee does not feel justified in recommending these specifications for publication this year as tentative it submits them for publication as information as appended to this report.

PROPOSED REVISION OF EXISTING TENTATIVE SPECIFICATIONS AND METHODS OF TEST

No. 1. *Tentative Specifications for High-Carbon Tar Cement for Use Cold in Repair Work (Cut-Back Product) (D 106 - 27 T).*[1]—In order to meet criticisms which have been received and to make these specifications conform more closely to customary practice the following revisions are recommended:

Section 1 (c).—Change to read as follows by the addition of the italicized figures and the omission of those in brackets:

(*c*) Distillation test on water-free material:

Total distillate, by weight, 0 to 170° C. (32 to 338° F.).........	[2.00] *1.00* to 8.00 per cent
Total distillate, by weight, 0 to 235° C. (32 to 455° F.).........	8.00 to 20.00 per cent
Total distillate, by weight, 0 to 270° C. (32 to 518° F.).........	[18.00 to 30.00] *16.00 to 28.00* per cent
Total distillate, by weight, 0 to 300° C. (32 to 572° F.).........	not more than [35.00] *36.00* per cent
Residue, by weight.........	not less than [65.00] *64.00* per cent

It is recommended that these specifications as revised be continued as tentative.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 940 (1927); also 1927 Book of A S T.M. Tentative Standards, p. 482.

No. 2. *Tentative Specifications for Low-Carbon Tar Cement for Use Cold in Repair Work (Cut-Back Product) (D 107 - 27 T).*[1]—For reasons mentioned in connection with the previous specifications the following revisions are recommended:

Section 1 (c).—Change to read as follows by the addition of the italicized figures and the omission of those in brackets:

(*c*) Distillation test on water-free material:

Total distillate, by weight, 0 to 170° C. (32 to 338° F.).........	[3.00 to 10.00] *1.00 to 8.00* per cent
Total distillate, by weight, 0 to 235° C. (32 to 455° F.).........	8.00 to 20.00 per cent
Total distillate, by weight, 0 to 270° C. (32 to 518° F.).........	[18.00 to 30.00] *16.00 to 28.00* per cent
Total distillate, by weight, 0 to 300° C. (32 to 572° F.).........	not more than [38.00] *36.00* per cent
Residue, by weight.........	not less than [62.00] *64.00* per cent

It is recommended that these specifications as revised be continued as tentative.

No. 3. *Tentative Method of Test for Residue of Specified Penetration (D 243 - 26 T).*[2]—During the past year the Section on Asphalt Content completed an extensive series of collaborative tests comparing the present method, in which a flat bottom can and air bath are used, with the substitution of a hemispherical iron dish and flask heater. The results demonstrated that while the degree of accuracy of the test is not impaired, less time for heating is required with the new apparatus, and the percentage of residues are slightly lower, amounting to from one to two per cent for the samples tested. As the time of testing is considered to be a very important factor the following revisions are recommended:

Sections 2, 3 and 4.—Omit the present Sections 2, 3 and 4 describing the container, heating bath and hot plate and substitute therefor the following:

2. The apparatus shall consist of an iron dish, flask heater, thermometer, Bunsen burner, tripod and stand with a thermometer clamp. The dish, flask heater and thermometer shall be as specified in Sections 3, 4 and 5.

3. The container for holding the sample to be tested shall be a hemispherical iron dish having the following dimensions:

Diameter at the top, outside..................	12.7 cm. ±0.3 cm.
Depth, inside..................................	5.7 cm. ±0.2 cm.
Radius of curvature, inside...................	6.0 cm. ±0.1 cm.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 942 (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 484.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, p. 889 (1926); also 1927 Book of A.S.T.M. Tentative Standards, p. 513.

NOTE.—A hemispherical iron sand bath, deep form of five inches diameter, should meet these requirements.

4. The flask heater shall be in the form of a truncated cone, with a diamete at the top of approximately 18.0 cm., a diameter at the bottom of approximately 5.2 cm., and a height of approximately 7.0 cm. It shall be made of sheet iron of about No. 22 gage with asbestos strips riveted to the sides, and with a sheet iron shield at the bottom.

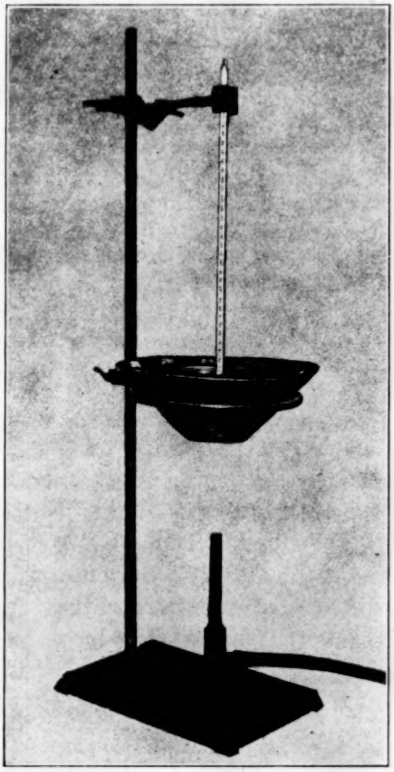

FIG. 1.—Evaporation Apparatus.

Figure 1.—Omit the present Fig. 1 showing a cast-iron air-bath

Figure 2.—Replace the present Fig. 2 showing the assembly of the apparatus with a figure conforming to the accompanying Fig. 1, changing the designation from Fig. 2 to Fig. 1.

Section 7.—Change the first sentence of this section to read as follows by the addition of the italicized words and the omission of those in brackets, and change the reference in the last sentence from Fig. 2 to Fig. 1:

> One hundred grams (100.00 ±0.10 g.) of the material to be tested shall be weighed into a tared container, which shall then be placed in the [air-bath] *flask heater* in position to be heated [by the hot plate].

Section 8.—Change the second sentence of the second paragraph to read as follows by the addition of the italicized words and the omission of those in brackets:

> When it is supposed that the residue will show the required penetration, the bitumen on the thermometer which may be readily scraped off shall be returned to the container, which then shall be removed from the [air-bath] *flask heater*, cooled and weighed.

Section 11.—Change from its present form: namely,

> 11. The results of the test shall be considered as correct within a range of 1.0 per cent.

to read as follows:

> 11. Duplicate determinations should not differ by more than 1.0 per cent with the same operator nor more than 2.5 per cent between different laboratories.

It is recommended that this method of test as revised be continued as tentative.

No. 4. *Tentative Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment (D 20 - 27 T)*[1].—As the result of a large amount of cooperative work relative to improvement in apparatus, this method of test has been revised in accordance with revisions which are also being proposed this year by Committee D-7 on Timber in connection with the Tentative Method of Test for Distillation of Creosote Oil (D 246 -27 T). The test results obtained in this cooperative work are of such value that they are printed as Appendix III to this report. The revisions recommended consist of the following:

Section 4.—Change the second sentence to read as follows by the addition of the italicized words and the omission of those in brackets:

> The cover (top) may be of transit board *made in two parts, or it may be of* galvanized iron lined with ⅛-in. asbestos [or of other suitable insulating material].

Figure 2.—Change Fig. 2 to show a division of the cover into two semicircular parts, and an opening with a diameter of 27 mm. ± 1 mm. It is recommended that this method of test as revised be continued as tentative.

No. 5. *Tentative Methods of Testing Bituminous Emulsions (D 244 - 26 T)*[2].—As the result of investigations relative to the type of still to be used in the distillation of bituminous emulsions the following revisions are recommended:

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 954 (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 505.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, p. 894 (1926); also 1927 Book of A.S.T.M. Tentative Standards, p. 518.

Section 4.—Change the first sentence to read as follows by the addition of the italicized words and the omission of those in brackets:

> 4. The apparatus shall consist of [a copper] *an iron* still, 6 in. by 3½ in. in inside diameter with an air adjustable ring burner to fit the still.

Figure 1.—Change the words "Copper Still" to read "*Iron Still.*" It is recommended that these methods as revised be continued as tentative.

PROPOSED ADVANCEMENT TO STANDARD OF EXISTING TENTATIVE METHOD OF TEST

No criticisms having been received on the following tentative method of test, the committee recommends that it be advanced to standard:

Tentative Method of Decantation Test for Sand and Other Fine Aggregates (D 136 - 22 T).[1]

NEW METHOD OF TEST AND RECOMMENDED PRACTICE SUBMITTED AS TENTATIVE

The following new method of test and recommended practice, appended hereto,[2] are recommended for publication as tentative:

1. Tentative Method of Test for Abrasion of Gravel;
2. Tentative Recommended Practice for Bituminous Paving Plant Inspection.

In connection with the proposed tentative method of abrasion tests for gravel, results of cooperative work are published in Appendix I to this report.

The committee is submitting for publication as information Proposed Specifications for Portland-Cement Concrete for Pavements and Pavement Base, prepared by the Section on Concrete Pavements and Bases. These specifications appear as Appendix II to this report.

The results of the letter ballot of the committee upon the recommendations made in this report appear in Table I.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 802 (1922); also 1927 Book of A.S.T.M. Tentative Standards, p. 501.

[2] See pp. 940 and 956, respectively.—ED.

TABLE I.—ANALYSIS OF LETTER BALLOT VOTE.

Items	Affirmative	Negative	Not Voting
I. PROPOSED REVISIONS OF EXISTING TENTATIVE STANDARDS			
Tentative Specifications for High-Carbon Tar Cement for Use Cold in Repair Work (Cut-Back Product) (D 106 - 27 T)	34	0	48
Tentative Specifications for Low-Carbon Tar Cement for Use Cold in Repair Work (Cut-Back Product) (D 107 - 27 T)	34	0	48
Tentative Method of Test for Residue of Specified Penetration (D 243 - 26 T)	38	1	43
Tentative Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment (D 20 - 27 T)	38	0	44
Tentative Methods of Testing Bituminous Emulsions (D 244 - 26 T)	34	0	48
II. PROPOSED ADVANCEMENT OF TENTATIVE METHOD OF TEST TO STANDARD			
Tentative Method of Decantation Test for Sand and Other Fine Aggregates (D 136 - 22 T)	37	0	45
III. PROPOSED NEW TENTATIVE STANDARDS			
Tentative Method of Test for Abrasion of Gravel	32	0	50
Tentative Recommended Practice in Bituminous Paving Plant Inspection	35	1	46

The following officers were elected to serve for the ensuing two years: R. W. Crum, chairman; Prévost Hubbard, secretary.

This report has been submitted to letter ballot of the committee, which consists of 82 members; 49 members returned their ballots, of whom 45 have voted affirmatively, none negatively, and 4 have marked their ballots "not voting."

Respectfully submitted on behalf of the committee,

JULIUS ADLER,
Chairman.

PRÉVOST HUBBARD,
Secretary.

EDITORIAL NOTE

The proposed revisions of the Tentative Specifications for High-Carbon Tar Cement for Use Cold in Repair Work (Cut-Back Product); for Low-Carbon Tar Cement for Use Cold in Repair Work (Cut-Back Product); Method of Test for Residue of Specified Penetration; Test for Distillation of Bituminous Materials Suitable for Road Treatment; and Testing Bituminous Emulsions were accepted. The tentative specifications and methods in their revised form appear on pages 936, 938, 948, 943 and 952, respectively.

The Tentative Method of Decantation Test for Sand and Other Fine Aggregates was approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on September 1, 1928, and appears in the 1928 Supplement to Book of A.S.T.M. Standards.

The proposed Method of Test for Abrasion of Gravel; and Recommended Practice for Bituminous Paving Plant Inspection were accepted for publication as tentative and appear on pages 940 and 956, respectively.

APPENDIX I

REPORT OF SECTION ON PROPOSED TENTATIVE METHODS OF ABRASION TESTING OF GRAVEL

During the year tests were made on gravel by several testing laboratories using the proposed methods of abrasion testing of gravel being recommended by Committee D-4 for publication as tentative.[1] Four gradings of gravel were used: Grading *A*, 2 to ½ in.; Grading *B*, 1½ to ½ in.; Grading *C*, 1 to ½ in.; and Grading *D*, ¾ to ½ in. Detailed results of these tests are given in the accompanying Tables I to IV. For some reason, Grading *C* shows lower results in most cases than the other three. By referring to the tables, it will be seen that each laboratory that ran check tests obtained very close results. There did not seem to be any constant difference between the different gradings.

TABLE I.—RESULTS OF ABRASION TESTS OF GRAVEL REPORTED BY OHIO STATE DEPARTMENT OF HIGHWAYS.

Source of Material	Percentage of Wear			
	Grading A	Grading B	Grading C	Grading D
Portsmouth, Ohio	7.2	5.6	5.6	6.0
	6.0	4.4	4.0	6.8
	6.0	4.8	4.0	6.4
	6.0	4.4	4.4	6.6
Average	6.3	4.8	4.5	6.6
Zanesville, Ohio	4.0	3.2	2.4	5.2
	3.2	3.6	2.6	5.2
	3.6	3.2	2.4	5.6
	3.6	3.6	2.6	5.6
Average	3.8	3.4	2.5	5.4
South Columbus, Ohio	5.6	4.0	3.8	6.2
	5.8	4.2	4.0	6.2
	5.0	4.0	4.0	7.2
	6.4	4.0	4.2	7.6
Average	5.6	4.0	4.0	6.8

Respectfully submitted on behalf of the section,

WALLACE F. PURRINGTON,
Chairman.

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[1] See p. 940.—ED.

TABLE II.—RESULTS OF ABRASION TESTS OF GRAVEL REPORTED BY THE U. S. BUREAU OF PUBLIC ROADS.

Grading	Percentage of Wear				Deviation from Average			
					Maximum		Mean	
	Run 1	Run 2	Run 3	Average	Unit	Per Cent	Unit	Per Cent
ILLINOIS GRAVEL (EXACT LOCATION NOT KNOWN)								
A	10.4	10.0	10.6	10.3	0.3	3	0.2	2
B	8.3	7.4	9.4	8.4	1.0	12	0.7	8
C	7.6	6.7	6.3	6.9	0.7	10	0.5	7
D	15.4	13.5	14.6	14.5	1.0	7	0.7	5
POTOMAC RIVER GRAVEL								
A	10.5	11.0	8.2	9.9	1.7	17	1.1	11
B	8.4	8.6	9.5	8.8	0.7	8	0.4	5
C	7.5	6.7	6.7	7.0	0.5	7	0.4	6
D	10.1	11.9	10.8	10.9	1.0	9	0.6	6
DELAWARE RIVER GRAVEL								
A	4.2	4.0	4.4	4.2	0.2	5	0.1	2
B	2.9	2.9	2.7	2.8	0.1	4	0.1	4
C	3.4	4.2	3.0	3.5	0.7	20	0.4	11
D	6.2	6.8	6.8	6.6	0.4	6	0.3	5
RAPPAHANNOCK RIVER GRAVEL								
A	14.1	15.8	14.2	14.7	1.1	7	0.7	5
B	10.3	10.4	10.5	10.4	0.1	1	0.1	1
C	10.5	11.1	11.0	10.9	0.4	4	0.2	2
D	13.7	13.5	....	13.6	0.1	1	0.1	1
MASSACHUSETTS PIT GRAVEL								
A	12.9	13.8	12.6	13.1	0.7	5	0.5	4
B	10.8	12.1	12.7	11.9	1.1	9	0.7	6
C	12.9	12.6	11.5	12.3	0.8	6	0.6	5
D	14.6	16.0	16.0	15.5	0.9	6	0.6	4
ALABAMA LAKE GRAVEL								
A	17.2	17.1	17.6	17.3	0.3	2	0.2	1
B	14.6	13.9	15.5	14.7	0.8	5	0.6	4
C	15.4	15.4	14.6	15.1	0.5	3	0.4	3
D	16.9	15.9	15.0	15.9	1.0	6	0.6	4
ILLINOIS PIT GRAVEL								
A	6.2	6.4	6.1	6.2	0.2	3	0.1	2
B	5.2	4.0	4.8	4.7	0.7	15	0.4	9
C	3.9	3.1	3.4	3.5	0.4	11	0.3	9
D	5.1	...	...	5.1	...	..	...	..

TABLE III.—RESULTS OF ABRASION TESTS OF GRAVEL REPORTED BY STATE HIGHWAY LABORATORY, UNIVERSITY OF MICHIGAN.

Source of Material	Percentage of Wear			
	Grading A	Grading B	Grading C	Grading D
Grand Rapids, Mich	5.7	3.66	3.7	6.2
Green Oak, Mich	4.5	4.0	3.7	3.4
Grand Rapids, Mich	3.6	3.4	3.5	5.8
New Hudson, Mich	3.3	2.2	2.1	2.7
Ann Arbor, Mich	3.3	2.5	2.7	3.9
Oxford, Mich	2.9	2.5	2.7	3.5

TABLE IV.—RESULTS OF ABRASION TESTS OF GRAVEL REPORTED BY FOUR COOPERATING LABORATORIES.

Laboratory	Source of Material	Percentage of Wear			
		Grading A	Grading B	Grading C	Grading D
Standard Slag Co	Ironton, Ohio	7.3	6.7	6.0	6.9
	Ohio River near Pittsburgh	8.9	8.2	7.0	9.0
France Stone Co	Urbana, Ohio	4.50	11.80	5.40	7.28
New Hampshire State Highway Department	Claremont, N. H	24.3	23.4	24.2	....
	Cornish, N. H	16.9	18.6	18.2	....
	Randolph, N. H	14.2	12.5	11.9	16.8
	East Weare, N. H	13.9	12.8	8.8	15.3
	Milton, N. H	11.8	8.5	8.9	14.3
Louisiana State Highway Commission	Lewisville, Ark	13.9	13.1	11.1	12.8
	Delight, Ark	6.3	5.6	....	....
	Roseland, La	....	3.2	3.3	3.9

APPENDIX II

PROPOSED SPECIFICATIONS FOR PORTLAND-CEMENT CONCRETE FOR PAVEMENTS AND PAVEMENT BASE[1]

GENERAL CLAUSES

1. *Scope.*—These specifications cover requirements for the constituent materials, for proportioning and mixing, and curing and testing the concrete for use in the construction of concrete pavements and concrete bases. Only those construction features are included which are necessary for the proper use of the materials.

2. *Storage and Protection of Materials.*—No concrete aggregate shall be placed or stored on the finished subgrade and due precaution shall be used in storage to avoid the inclusion of foreign materials. Frozen aggregate or aggregate containing lumps of frozen material shall be thawed before using. Portland cement shall be stored on a dry floor in a weather-tight building. Proper protection of the materials as they are transported from the central proportioning plant to the mixer shall be provided by the contractor.

3. *Portland Cement.*—Portland cement shall be a standard brand of portland cement and shall conform to the requirements and tests of the Standard Specifications and Tests for Portland Cement (Serial Designation: C 9) of the American Society for Testing Materials.[2] A cubic foot of portland cement shall be considered as weighing 94 lb.

4. *Stock Piling of Coarse Aggregate.*—To avoid segregation the coarse aggregate as unloaded shall be spread out in horizontal layers not exceeding 4 ft. in thickness. In no case shall the formation of conical piles by the depositing of materials in one place be permitted. If the horizontal method of stock piling is not feasible, the coarse aggregate shall be shipped in at least two separate sizes. Should the coarse aggregate become segregated it shall be re-mixed so as to conform to the grading requirements of the specifications.

5. *Approval of Sources of Materials Supply.*—Sources of supply for portland cement, and fine and coarse aggregates shall be approved by the engineer before the shipment of materials is started. The source of mixing water shall likewise be approved before concrete mixing is begun.

6. *Devices for Measuring Materials.*—The contractor shall exercise due care to obtain accurate proportioning of every batch of concrete. He shall provide volumetric, weighing or inundation devices for measuring the aggregates, satisfactory to the engineer. He shall also provide a water-tight container of a capacity suitable to the engineer for checking the quantities of fine and coarse aggregate when inundation or volumetric means of proportioning are used.

7. *Central Mixing Plants.*—If a central mixing plant is used the concrete shall be placed before it has stiffened too much for proper finishing and shall not be used without re-mixing if segregation has taken place in transporting it.

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[1] These specifications appear as an appendix to the 1928 Report of Committee D-4 on Road and Paving Materials. They are published as information only and have not been issued as specifications of the Society.

[2] 1927 Book of A.S.T.M. Standards, Part II, p. 23.

NOTE.—Unless a special investigation is used to determine the maximum time of haul, it is suggested that a time limit of 30 minutes be specified.

8. *Re-tempered Concrete.*—Re-tempered concrete shall not be used.

QUALITY OF AGGREGATES

9. *Special Provisions.*—It is recognized that for certain purposes satisfactory results may be obtained with materials not conforming to these specifications. In such cases the use of fine and coarse aggregates not complying with these specifications should be authorized only under special provisions based upon laboratory studies of the possibility of designing a mixture that will yield concrete equivalent to the specified mixture made with material complying with these specifications in all respects.

Fine Aggregate

10. *General Characteristics.*—Fine aggregate shall consist of sand or other approved inert materials with similar characteristics, or a combination thereof, having hard, strong, durable particles and shall conform to the requirements of these specifications.

11. (*a*) *Deleterious Substances.*—The maximum amounts of deleterious substances shall not exceed the following values:

	PER CENT BY WEIGHT
Removed by decantation	3
Shale	1
Coal	1
Clay lumps	1
Other local deleterious substances (such as alkali, mica, coated grains, soft and flaky particles)	....

NOTE.—It is recognized that under certain conditions maximum percentages on deleterious substances less than those shown in the table should be specified.

(*b*) All fine aggregate shall be free from injurious amounts of organic impurities. Aggregates subjected to the colorimetric test for organic impurities and producing a color darker than the standard shall be rejected unless they pass the mortar strength test.

12. (*a*) *Grading.*—The fine aggregate shall be uniformly graded from coarse to fine and when tested by means of laboratory sieves[1] shall conform to the following requirements:

	PER CENT
Passing a ⅜-in. sieve	100
Passing a No. 4 sieve	(85) to (100)
Passing a No. 16 sieve	(45) to (80)
Passing a No. 50 sieve	(2) to (30)
Passing a No. 100 sieve	(0) to (5)

NOTE.—Percentages in parentheses are recommended but they may be altered to suit local conditions.

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[1] For detail requirements for these sieves see the Standard Specifications for Sieves for Testing Purposes (Serial Designation: E 11) of the American Society for Testing Materials, 1927 Book of A.S.T.M. Standards, Part II, p. 917.

(*b*) In case the concrete resulting from a mixture of aggregates complying with the extreme limits for grading, is not of a workable character or when finished does not exhibit a proper surface, either a fine aggregate having a greater percentage of fine material or a coarse aggregate having a smaller percentage of fine material shall be used.

13. *Mortar Strength.*—Fine aggregates, when subjected to the mortar strength test, shall have a tensile or compressive strength at the age of 7 and 28 days of not less than (100)[1] per cent of that developed by mortar of the same proportions and consistency made of the same cement and standard Ottawa sand.

Coarse Aggregate

14. *General Characteristics.*—Coarse aggregate shall consist of crushed stone, gravel, blast-furnace slag, or other approved inert materials of similar characteristics, or combinations thereof, having hard, strong, durable pieces, free from adherent coatings and conforming to the requirements of these specifications.

15. *Deleterious Substances.*—The maximum amounts of deleterious substances shall not exceed the following values:

	PER CENT BY WEIGHT
Removed by decantation	1
Shale	1
Coal	1
Clay lumps	½
Soft fragments	5
Other local deleterious substances (such as alkali, friable, thin, elongated or laminated pieces)	

NOTE.—It is recognized that under certain conditions maximum percentages on deleterious substances less than those shown in the table should be specified.

The sum of the percentages of shale, coal, clay lumps and soft fragments shall not exceed 5 per cent.

16. *Abrasion Test.*—An abrasion test for coarse aggregate to be used in concrete subject to abrasion is important, but no test limits are specified, due to the status of knowledge concerning suitable specification limits for this test.

17. *Durability.*—Coarse aggregate shall pass a suitable accelerated soundness test. Aggregates failing in the accelerated soundness test may be used if they pass a satisfactory freezing and thawing test.

18. *Weight of Slag.*—The minimum weight of blast-furnace slag shall conform to the following:

Base concrete	65 lb. per cu. ft.
Surface concrete (subject to abrasion)	70 lb. per cu. ft.

19. (*a*) *Grading.*—Coarse aggregate shall be uniformly graded, between the limits specified, and shall conform to the following requirements:

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[1] Percentages in parentheses are recommended but they may be altered to suit local conditions.

		PER CENT BY WEIGHT
Passing .... in. sieve[1] or screen	(maximum size)	not less than (95)
Passing .... in. sieve[1] or screen	(intermediate size)	not less than (40)
	(one-half maximum size)	not more than (75)
Passing .... in. sieve[1] or screen	(intermediate sizes)	not less than ....
	(as needed)	not more than ....
Passing No. 4 sieve[1] or screen		not more than 0 to 10

NOTE.—Where a range is shown the engineer should use an appropriate percentage within the limits recommended. The percentages in parentheses are recommended but may need to be altered to suit local conditions.

(*b*) In case the concrete resulting from a mixture of aggregates complying with the extreme limits for grading is not of a workable character or when finished does not exhibit a proper surface, either a fine aggregate having a greater percentage of fine material or a coarse aggregate having a smaller percentage of fine material shall be used.

METHODS OF SAMPLING AND TESTING

20. *Methods of Testing.*—The properties enumerated in these specifications shall be determined in accordance with the following methods of test of the American Society for Testing Materials, except as specified in Paragraphs (*e*), (*g*), (*i*) and (*j*).

(*a*) *Sampling.*—Standard Methods of Sampling Stone, Slag, Gravel, Sand and Stone Block for Use as Highway Materials, Including Some Material Survey Methods (Serial Designation: D 75).[2]

(*b*) *Sieve Analysis.*—Standard Method of Test for Sieve Analysis of Aggregates for Concrete (Serial Designation: C 41).[2]

(*c*) *Decantation Test.*—Standard Method of Decantation Test for Sand and Other Fine Aggregates (Serial Designation: D 136).[3]

(*d*) *Organic Impurities.*—Standard Method of Test for Organic Impurities in Sands for Concrete (Serial Designation: C 40).[2]

(*e*) *Mortar Strength.*—Methods of Making Compression and Tension Tests of Fine Aggregate for Concrete as adopted by the American Association of State Highway Officials.

(*f*) *Compressive Strength.*—Standard Methods of Making Compression Tests of Concrete (Serial Designation: C 39).[2]

(*g*) *Soundness.*—Method of Test for Soundness of Coarse Aggregate (Sodium Sulfate Soundness Test) as adopted by the American Association of State Highway Officials.[4]

(*h*) *Freezing and Thawing.*—Method of Freezing and Thawing Tests of Drain Tile as described in the Standard Specifications for Drain Tile (Serial Designation: C 4).[2]

(*i*) *Shale and Coal.*—Method of Test for Percentage of Shale in Aggregate as adopted by the American Association of State Highway Officials.[5]

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[1] The question whether round or square openings shall be used for testing aggregates is now being studied by the Section on Coarse Screens of the Technical Committee on Size and Shape of Committee E-1 on Methods of Testing.

[2] 1927 Book of A.S.T.M. Standards, Part II.

[3] 1928 Supplement to Book of A.S.T.M. Standards, p. 161.

[4] Appendix II, 1928 Report of Committee C-9 on Concrete and Concrete Aggregates, see p. 361.

[5] Appendix III, 1928 Report of Committee C-9 on Concrete and Concrete Aggregates, see p. 362.

(*j*) ***Soft Fragments.***—Method of Test for Quantity of Soft Pebbles in Gravel as adopted by the American Association of State Highway Officials.[1]

(*k*) ***Moisture.***—Tentative Method of Test for Field Determination of Surface Moisture in Fine Aggregate (Serial Designation: C 70 - 28 T).[2]

(*l*) ***Consistency.***—Tentative Method of Test for Consistency of Portland-Cement Concrete (Serial Designation: D 138 - 26 T).[3]

(*m*) ***Abrasion.***—If abrasion tests are made the following methods of tests are recommended:

(1) *Abrasion of Rock.*—Standard Method of Test for Abrasion of Rock (Serial Designation: D 2).[4]

(2) *Abrasion of Gravel.*—Tentative Method of Test for Abrasion of Gravel (Serial Designation: D 289 - 28 T).[5]

(3) *Abrasion of Crushed Slag.*—Standard Method of Test for Abrasion of Rock (Serial Designation: D 2),[4] except that for specific gravities lower than 2.2 a 4000 g. sample shall be used.

PROPORTIONING AND MIXING[6]

21. *Basis for Proportioning.*—The proportioning of the mix shall be based upon a specified minimum cement content per cubic yard of finished concrete, and upon a specified maximum ratio of water to cement, such that concrete of workable consistency as defined by the specified maximum slump, see Section 25, will produce concrete having the minimum strength required by the design.

22. *Proportioning for Specific Cases.*—When it is practicable to make preliminary laboratory tests using the particular materials available for the work, proportions shall be based upon studies of quality and economy.[7]

23. *Unit of Measure.*—The unit of measure for cement and aggregates shall be the pound or cubic foot. Ninety-four pounds of cement (1 sack or ¼ bbl.) shall be considered as 1 cu. ft. The unit of measure for water shall be the U. S. gallon (231 cu. in.).

24. (*a*) *Measurement of Cement, Aggregates and Water.*—Measurement of bulk cement shall be made by weight. Cement in sacks of 94 lb. net weight may be used as 1 cu. ft.

(*b*) Fine aggregate (see Note) shall be weighed or measured by volume in an inundated condition. Coarse aggregate shall be measured by volume or weight. In volume measurement of aggregates, whether by inundation in the case of fine aggregates or loose volume in the case of coarse aggregates, the volume shall be adjusted to give the correct equivalent of the dry and rodded quantities specified.

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[1] Appendix IV, 1928 Report of Committee C-9 on Concrete and Concrete Aggregates, see p. 363.

[2] See p. 832.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, p. 874 (1926); also 1928 Book of A.S.T.M. Tentative Standards, p. 518.

[4] 1927 Book of A.S.T.M. Standards, Part II.

[5] See p. 940.

[6] These requirements for proportioning and mixing are based on the "Recommended Revision of Chapter V of the 1924 Report of the Joint Committee on Standard Specifications for Concrete and Reinforced Concrete," recommended by Committee C-9 on Concrete and Concrete Aggregates, see 1928 Report of Committee C-9, *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 341 (1928).

[7] See Reports Sub-Committee on Design of Concrete of Committee C-9 on Concrete and Concrete Aggregates for 1927 and 1928, *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 345 (1927) and *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 346 (1928), respectively.

NOTE.—Measurement of fine aggregate by loose volume is not recommended. If measurements must be made by loose volume, the engineer shall determine the bulking of the aggregates above their dry rodded volumes due to moisture and method of field measurement and shall determine the volume of the measure to be used in proportioning on the job.

(*c*) The free moisture carried by the aggregates shall be considered as part of the mixing water and the quantity of water to be added to the batch shall be adjusted accordingly, so that the maximum water content shall not exceed that specified.

25. *Proportions and Consistency.*—Concrete shall be mixed in the proportions specified in Table I.

TABLE I.—PROPORTIONS FOR MIXING CONCRETE.

	Modulus of Rupture at 28 Days Assumed as Basis for Design, lb per sq. in.	Maximum Permissible Water Content, Gallons per 94-lb. Sack of Cement	Limiting Slump, In.		Cement Sacks per Cubic Yard of Finished Concrete, Minimum	Proportions, Cement to Fine to Coarse Aggregate
			Minimum	Maximum		
Pavements..	600	[a]	$\frac{1}{2}$	$1\frac{1}{2}$	[b]	[c]
Bases........	500	[a]	$\frac{1}{2}$	2	[b]	[c]

[a] The maximum permissible water content should be based upon preliminary laboratory studies if possible. If this is impracticable, and if data from previous field experience is not available, the following values are suggested:

Modulus of Rupture, lb. per sq. in.	Maximum Permissible Water Content
600	5.5 gal. per 94-lb. sack of Cement
500	6.5 gal. per 94-lb. sack of Cement

[b] To be estimated from the proportions and maximum permissible water content specified.

[c] Proportions shall be selected that will yield concrete of the specified consistency when mixed with the maximum permissible water content, under average conditions. The method of proportioning, whether by dry weight or dry rodded volume, shall be stated.

26. *Tests.*—To assure a concrete of the required strength the engineer may require the making of strength tests during the progress of the work. Such tests shall be made in accordance with the current standards of the American Society for Testing Materials.

27. (*a*) *Mixing.*—The mixing of concrete, unless otherwise authorized by the engineer, shall be done in a batch mixer of approved type which will insure a uniform distribution of the materials throughout the mass, so that the mixture is uniform in color and homogeneous. The mixing of each batch shall continue not less than one minute after all the materials are in the mixer, during which time the mixer shall rotate at a peripheral speed of about 200 ft. per minute.

(*b*) The mixer shall be equipped with a suitable charging hopper, water storage, and a water-measuring device controlled from a case which can be kept locked and so constructed that the water can be discharged only while the mixer is being charged. It shall also be equipped with an attachment for automatically locking the discharge lever until the batch has been mixed the required length of time after all materials are in the mixer. The entire contents of the drum shall be discharged after each charge has been mixed the required length of time. The mixer shall be cleaned at frequent intervals while in use. The volume of the mixed material per batch shall not exceed the manufacturer's rated capacity of the mixer.

PROTECTION AND CURING

28. *Protection.*—The concrete pavement or base shall be protected against rapid drying by covering with No. 10 or 12 saturated burlap for 24 hours[1] laid directly upon the surface immediately after the final belting of the concrete. The burlap shall be kept continuously wet by sprinkling. Unless these requirements are complied with, work shall immediately be suspended.

29. *Curing.*—The burlap shall be removed after 24 hours,[1] and the pavement cured in accordance with one of the following methods:

(*a*) *Earth Curing.*—The edges of the pavement shall be banked and the entire surface covered with at least 2 in. of earth, the thickness of the covering to be determined after the earth has been thoroughly saturated with water. The earth shall be thoroughly saturated with water each day for a period of 7 days, and the earth shall remain on the surface for at least 14 days from the time of its application.

(*b*) *Straw or Hay Curing.*—The entire surface shall be uniformly covered with straw or hay. The covering material shall be at least 6 in. in thickness, using at least three bales of approximately 100 lb. each, for each 100 square yards of pavement surface. The straw or hay shall be thoroughly saturated each day for a period of 7 days and the covering material shall remain on the surface for at least 14 days from the time of its application. It shall then be removed and disposed of so as to leave the road in a sightly condition, but under no circumstances shall it be burned on the pavement surface, or in close proximity with the edges.

(*c*) *Ponding Method.*—The surface shall be flooded with water by means of earth dikes, and shall be kept covered with water for a period of at least seven days.

(*d*) *Calcium Chloride Curing:*

(1) *Surface Method.*—The surface (see Note) shall be uniformly covered with flaked calcium chloride, applied at the rate of not less than 2 nor more than 3 lb. per sq. yd. of pavement, spread by a squeegee or suitable mechanical device so that a uniform distribution is obtained. Any lumps shall be entirely removed from the surface of the pavement.

NOTE.—When curing with calcium chloride applied on the surface, the burlap shall be removed as soon as practicable after the concrete has taken its final set, and not later than 10 A. M. on the day following the placing of the concrete.

The calcium chloride shall not be applied until a period of at least ten hours has elapsed after the pavement is laid, and shall not be applied during a rainfall. If a rainfall occurs within a period of two hours following the application of the calcium chloride, an additional application must be made.

(2) *Integral Method.*—The calcium chloride shall be added in solution to the mix in the proportion of 2 lb. of calcium chloride per sack of cement; or, when maximum acceleration is desired, in an amount found satisfactory by tests and specified by the engineer. In cold weather this amount may be increased, but not in excess of 4 lb. of calcium chloride to each sack of

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[1] For exception to this requirement, see Section 29(*d*).

cement. In rich mixes, and in extremely warm weather, it may be found desirable to reduce the amount of calcium chloride for each sack of cement. The calcium chloride solution shall be considered as part of the mixing water in calculating the water-cement ratio. A positive and approved method shall be used for adding the calcium chloride solution in the drum of the mixer at the time of mixing each batch of concrete, and the solution shall always accompany or follow the addition of the required water.

Calcium Chloride Solution.—The solution which is to be added to the mix shall contain 4 lb. of calcium chloride per gallon of solution. The calcium chloride solution may be made by filling a 50-gal. barrel about two-thirds full of water, to which add 200 lb. (two bags) of flake calcium chloride, and stir until all the material is dissolved. The calcium chloride shall conform to the Tentative Specifications for Calcium Chloride for Dust Prevention (Serial Designation: D 98 - 22 T) of the American Society for Testing Materials.[1] Add enough water to fill the 50-gal. barrel and stir to make the solution uniform throughout. For 2 lb. of calcium chloride per bag of cement, add two quarts of the standard calcium chloride solution.

FIELD TESTS

30. *Compression Tests.*—Specimens shall be made and tested in accordance with the Standard Methods of Making and Storing Specimens of Concrete in the Field (Serial Designation: C 31) and the Standard Methods of Making Compression Tests of Concrete (Serial Designation: C 39) of the American Society for Testing Materials.[2]

31. *Transverse Strength.*—The object of this test is to afford data which will permit the opening of the road to traffic as soon as the proper strength has been gained as well as to determine the quality of the concrete.

32. *Apparatus.*—The machine shall conform to the principles outlined in the following paragraph.

The following principles should be secured in the design of the particular apparatus that may be used to make transverse tests of concrete beams whether they are field or laboratory tests:

(*a*) The distance between supports and points of load application shall remain constant for a given piece of apparatus.

(*b*) The load shall be applied normal to the initial position of the neutral plane of the beam and in such a manner as to avoid eccentricity of loading.

(*c*) The direction of reaction shall, at all times throughout a given test, be parallel to the direction of the applied load. If this be vertical, then the direction of the reactions shall be vertical and shall remain so throughout the test until rupture occurs.

NOTE.—The more common devices, which, either singly or in combination, essentially secure such a relation between the applied loads and consequent reactions, include link supports, rocker bearings, spherical bearings or flexure plates.

(*d*) The application of the load shall be such as to secure uniform increments of load for equal time periods. This operation requirement demands that the operation of the apparatus be "smooth" and free from sudden shocks.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 790 (1922); also 1928 Book of A.S.T.M. Tentative Standards, p. 469.

[2] 1927 Book of A.S.T.M. Standards, Part II, pp. 108 and 112, respectively.

(*e*) The ratio of distance between point of load application and the nearest reaction to depth of beam shall be not less than $1\frac{1}{2}$ to 1.

NOTE.—The effect of this ratio on modulus of rupture requires further investigation.

33. *Size of Test Specimens.*—The size of the test beams shall be 6 by 6 by 36 in., provided the maximum size of aggregate does not exceed $2\frac{1}{2}$ in. A 36-in. length is sufficient to obtain two tests on the same beam.

34. *Number of Specimens.*—At least two beams shall be made for each 1000 sq. yd. of pavement surface.

35. *Age of Test.*—Tests shall be made at 28 days, unless it is desirable to open the pavement to traffic as soon as possible, in which case tests may be made at 7 and 10 days.

36. *Methods of Molding.*—The concrete for the test specimens shall be taken after it is deposited on the subgrade, and shall be carried to the molds. The material shall not be taken at random, but each shovelful shall represent the true proportions of the mortar and coarse aggregate as they occur in the mix. Concrete shall be taken from a batch representative of the average consistency of the concrete being placed. The consistency of the concrete may be determined by the slump test.

The molds shall be filled to overflowing and then spaded along the sides, care being used to be sure coarse aggregate is not wedged along the sides or the corners of the forms. The top shall be carefully struck off so as to give it a true and even surface.

37. *Curing.*—Every precaution shall be used to secure the same curing conditions in the test specimens as obtained in the concrete pavement, so that the tests will directly represent the strength of the concrete in the pavement.

38. *Marking.*—Specimens shall be properly identified as to date of molding and to location of pavement represented. The weather conditions pertaining at the time of molding shall also be noted.

APPENDIX III

RESULTS OF COOPERATIVE DISTILLATION TESTS BY THE COMMITTEE ON MATERIALS OF THE A.A.S.H.O. AND THE SECTION ON DISTILLATION OF COMMITTEE D-4

For the purpose of carrying out a number of cooperative distillation tests, using both the Engler and the E-1 flasks, a joint meeting was held of the members of the Sub-Committee on Bituminous and Chemical Testing Problems of the Committee on Materials of the American Association of State Highway Officials and the Section on Distillation of Committee D-4 on Road and Paving Materials, at the laboratory of the New Jersey State Department of Conservation and Development, the laboratory having been placed at the disposal of the committees through the courtesy of Mr. R. B. Gage, Chemical Engineer of the New Jersey State Department.

Representatives of the U. S. Bureau of Public Roads, of the State Highway Laboratories of Connecticut, New Jersey, New York, Rhode Island, Ohio, Pennsylvania, and of the American Tar Co., the Barrett Co., and the United Gas Improvement Co. cooperated in the work. The actual distillation tests were carried out by five operators. These men brought with them complete sets of their apparatus for carrying out the distillation tests, using both the method employing the Engler flask and the present Tentative Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment (D 20 – 27 T) using the E-1 flask.

Distillation Results:

Two samples of material were used, one made from water-gas-tar base furnished by the United Gas Improvement Co. and the other coal-tar base furnished by the American Tar Co. The results are given in Table I.

The sample of water-gas-tar base material was the one first distilled, and it will be noted that there is considerably closer agreement among the different operators in the distillation on the second sample, that is, the coal-tar sample. The average figures are summarized in Table II.

The committee felt that the results of this series of cooperative tests demonstrated that if the operating conditions were in accordance with the specifications that different operators should certainly check very closely on the results of their distillation and that there was no evidence of any large variation between the results of the two methods of testing, the average figure being of the order of 2 per cent.

TABLE I.—RESULTS OF COOPERATIVE DISTILLATION TESTS.

Room Temperature, 23° C.; Barometer, 758 mm.

Operator	Time to First Drop		Temperature at First Drop, deg. Cent.	Distillation Time		Total Time		Rate of Distillation, Drop per Minute	Distillation Values, per cent			
	Min.	Sec.		Min.	Sec.	Min.	Sec.		0 to 170° C.	0 to 235° C.	0 to 270° C.	0 to 300° C.
WATER-GAS-TAR BASE: E-1 FLASK												
The Barrett Co.	5	40	...	..	..	..	..	55	4.2	12.2	18.2	26.0
Conn. State Highway Dept.	6	30	...	..	..	..	..	60	3.3	13.6	20.0	27.0
N. J. State Dept.	9	30	120	11	30	21	0	55	3.5	14.7	20.7	28.0
Penna. State Highway Dept.	5	5	125	..	..	..	..	58–63	3.3	13.5	19.4	26.8
United Gas Improvement Co.	8	5	110	12	5	20	50	55–65	3.6	14.9	20.5	27.8
Plant Determination	...	...	...	...	...	...	...	...	3.6	13.7	20.1	27.2
WATER-GAS-TAR BASE: ENGLER FLASK												
The Barrett Co.	6	22	115	25	46	32	8	56	6.3	14.7	23.2	29.7
Conn. State Highway Dept.	4	0	120	15	0	19	0	50	6.3	13.9	21.3	26.4
N. J. State Dept.	7	5	105	26	54	33	0	45	5.5	14.7	21.7	31.7
Penna. State Highway Dept.	5	40	...	16	20	22	0	55–60	5.5	14.6	21.3	30.3
United Gas Improvement Co.	5	45	110	..	..	..	..	40	5.6	14.2	20.1	27.3
Plant Determination	...	...	...	...	...	...	...	...	5.6	14.6	21.5	31.1
COAL TAR BASE: E-1 FLASK												
The Barrett Co.	6	20	132	12	15	18	35	60	1.8	11.6	18.7	25.3
Conn. State Highway Dept.	7	25	125	11	57	19	22	60	2.5	11.8	18.1	25.9
N. J. State Dept.	8	47	138	10	13	19	0	62.5	2.0	11.5	18.2	25.8
Penna. State Highway Dept.	6	20	123	11	40	18	0	60	2.0	11.3	18.6	26.5
United Gas Improvement Co.	6	30	118	12	0	18	30	60	1.6	10.8	17.7	25.0
COAL TAR BASE: ENGLER FLASK												
The Barrett Co.	5	38	84	12	14	17	52	59	3.3	13.0	20.3	26.0
Conn. State Highway Dept.	6	0	...	15	0	21	0	55	3.9	13.3	20.3	25.6
N. J. State Dept.	9	45	93	15	25	25	10	60	3.3	12.4	20.4	25.8
Penna. State Highway Dept.	7	0	100	17	0	24	0	60	2.8	12.9	20.6	26.4
United Gas Improvement Co.	5	15	105	13	45	19	0	60	3.2	13.5	21.4	28.3

TABLE II.—SUMMARY OF AVERAGE FIGURES ON DISTILLATION TESTS.

	Water-Gas-Tar Sample			Coal-Tar Sample			Average Difference
	Engler Flask Distillation	E-1 Flask Distillation	Difference	Engler Flask Distillation	E-1 Flask Distillation	Difference	
Distillate 0 to 170° C.	5.8	3.6	2.2	3.3	2.0	1.3	1.8
Distillate 0 to 235° C.	14.4	13.8	0.6	13.0	11.4	1.6	1.1
Distillate 0 to 270° C.	21.5	19.8	1.7	20.6	18.3	2.3	2.0
Distillate 0 to 300° C.	29.1	27.1	2.0	26.4	25.7	0.7	1.4

Comparison with Results of Other Tests:

The Section on Distillation has been studying the comparative results obtained with the E-1 and the Engler flask for some three years. Two sets of samples were sent out in 1925 and the results reported in 1926. These covered cooperative distillation by seven laboratories.

In the spring of 1927 another set of samples was sent out and some eight laboratories reported on the results. In the present cooperative tests five laboratories participated. There are included, also, some average results obtained by two laboratories, the United Gas Improvement Co. and the New Jersey State Department, on a relatively large number of samples so that these results should have somewhat the same weight as a larger number of laboratories on single samples:

Material	Average Differences in Distillation Values			
	0 to 170° C.	0 to 235° C.	0 to 270° C.	0 to 300° C.
SUMMARY OF AVERAGE DIFFERENCES				
Tar for Surface Treatment, Cold Application	0.2	2.5	2.3	1.9
Tar for Use Cold in Repair Work	1.6	1.9	2.1	1.6
Tar for Surface Treatment, Hot Application	0.0	1.1	2.8	1.2
Tar for Penetration[a]	0.0	0.5	2.4	2.1
Mean Maximum Deviation	±0.6[b]	±1.6	±1.3	±1.0

[a] Average of results from New Jersey State and United Gas Improvement Co. only.
[b] Includes only tar for use cold in repair work.

A study of these results shows that the experimental work indicates that there is an apparent difference between the distillation figures obtained with these two methods, and that the Engler method gives a higher figure at all points in the distillation. However, with the exception of the distillate to 170° C. in the case of the material for use cold in repair work and the distillate to 270° C. in the case of material for surface treatment, hot application, the differences are not greater than might occur by the application of the maximum deviation figures.

A summary of all of the work indicates that we might assume a difference of 2 per cent between these two methods of distillation. In view of the fact that there are only two A.S.T.M. specifications that contain a minimum requirement, namely, the tentative specification for tar cement for use cold in repair work (Specifications D 106 - 27 T and D 107 - 27 T), if the minimum were reduced 2 per cent, it should not be necessary to make any other changes in the distillation requirements, except that such lowering will be equivalent to an apparent spreading of the requirements by this amount.

Respectfully submitted on behalf of the Joint Committee of the Sub-Committee on Bituminous and Chemical Testing Problems, A.A.S.H.O., and of the Distillation Section, Committee D-4, A.S.T.M.,

W. H. FULWEILER,
Chairman, Distillation Section,
Committee D-4, A.S.T.M.

H. M. MILBURN,
Chairman, Sub-Committee on Bituminous and Chemical Testing Problems, Committee on Materials, A.A.S.H.O.

REPORT OF COMMITTEE D-5

ON

COAL AND COKE

During the past year, Committee D-5 has held two meetings, one at Washington, D. C., on March 22, the other at the annual meeting of the Society prior to the presentation of this report. A new Sub-Committee on Pulverization Characteristics of Coal has been formed. This sub-committee is to investigate laboratory methods of test to determine differences in pulverization characteristics of various coals in connection with the commercial preparation of powdered fuel. Another sub-committee is being formed to consider simplification of foundry coke specifications. The Division of Simplified Practice of the Department of Commerce has requested the Society to consider foundry coke specifications, since the present standard specifications for foundry coke may require considerable revision to cover the various grades of coke now available for foundry use, especially in regard to variations in physical properties. The American Foundrymen's Association is interested in these specifications and will cooperate through the sub-committee having jurisdiction over the specifications.

The Tentative Method of Test for Fineness of Powdered Coal (D 197 – 26 T) is recommended to be continued as tentative as the investigation of sampling methods is not completed. The Tentative Definitions of Terms Relating to Coal and Coke (D 121 – 27 T) are recommended to be continued as tentative pending their revision by Sub-Committee II on Nomenclature and Definitions. The Tentative Methods for the Determination of Sulfur in Coal and Coke (D 271 – 27 T) by the Bomb-Washing and Sodium Peroxide Fusion Methods are recommended for continuation as tentative.

Sub-Committee I on Methods of Testing has revised the method of determination of phosphorus in coal and coke as given in the Standard Methods of Laboratory Sampling and Analysis of Coal and Coke (D 271 – 27), the revision being given in detail below. The sub-committee recommended a method of tumbler test for coke which was accepted by Committee D-5 and is being recommended for publication as a tentative method.

Sub-Committee V on Tolerances has been active and sampling experiments are being made to obtain information on allowable tolerances in case different samplers collect samples of the same lot of coal. The data from the preliminary sampling experiments are to be used to interest various organizations in the need of a thorough investigation as to sampling various types of coal under different conditions of coal handling. Funds will be solicited from these organizations to pay for the full time services of one man to conduct the sampling at various coal consuming centers.

Proposed Revisions of Existing Standard Methods of Test

Standard Methods of Laboratory Sampling and Analysis of Coal and Coke (D 271 - 27).[1]—The methods for determination of phosphorus in the ash of coal and coke as given in the standard methods have been revised so as to give more detailed instructions as to procedure. This revision should be of value to coal chemists who have had little experience in determining phosphorus. The revised methods are intended to replace the methods for phosphorus as given on p. 550 of the 1927 Book of A.S.T.M. Standards, Part II. Committee D-5 recommends that the revisions given below be accepted for publication as a tentative revision of the standard methods to replace the present Sections 21 and 22:

Determination of Phosphorus in Ash

(For Coal and Coke)

Solution Required

21. *Solution Required.—Molybdate Solution.*—Dissolve 65 g. of molybdic acid (85-per-cent) in a mixture of 143 cc. of NH_4OH (sp. gr. 0.90) and 142 cc. of water. Add this solution slowly, with constant stirring, to 715 cc. of HNO_3 (sp. gr. 1.20). If the solution is cloudy, add two drops of a solution of ammonium phosphate (20-per-cent) and allow the precipitate which forms to settle Filter the solution into bottles and, if necessary, re-filter just before using. If the molybdic acid used is 100-per-cent, 56 g. should be taken instead of 65 g.

Method

Method No. 1, for All Cases:

22. *Determination of Phosphorus in Ash.*—Add to the ash from a 5-g. sample, in a platinum crucible, 10 cc. of concentrated HNO_3 and 3 to 5 cc. of HF. Evaporate the liquid and fuse the residue with 3 g. of Na_2CO_3. If unburned carbon is present, mix 0.2 g. of $NaNO_3$ with the carbonate. Leach the melt with water and filter the solution. Ignite the residue, fuse with Na_2CO_3 alone, leach the melt with water and filter the solution. Just acidify with HNO_3 the combined filtrate held in a flask, add 3 to 5 cc. of concentrated HNO_3 in excess, and concentrate to a volume of 100 cc. Add 6 g. of NH_4NO_3, bring the temperature of the solution to 80° C., add 50 cc. of molybdate solution and shake the flask for 10 minutes. When the precipitate has settled, filter and wash the precipi-

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 535.

tate, until free from acid, with a KNO_3 solution (2-per-cent). Place the filter paper with the precipitate in the flask, add 25 cc. of recently boiled distilled water, and macerate the filter paper with a glass stirring rod. Add a measured excess of standard NaOH solution and agitate the solution to completely dissolve the precipitate. Add 3 drops of phenolphthalein solution as an indicator and titrate the excess NaOH with a standard HNO_3 solution. The alkali solution may well be made equal to 0.00025 g. of phosphorus per cubic centimeter, or 0.005 per cent for a 5-g. sample. Such a solution would be 0.926 of 0.2 *N*.[1]

NOTE.—The advantage of the use of HF in the initial attack of the ash lies in the resulting removal of silica. Fusion with alkali carbonate is necessary for the elimination of titanium, which if present and not removed will contaminate the phospho-molybdate and is said to sometimes retard its precipitation.

Method No 2, when Titanium is Low:

23. When titanium is so low as to offer no objection, decompose the ash as described in Section 22, *Method No. 1*, but carry the evaporation only to a volume of about 5 cc. Dilute the solution with water to 30 cc., boil and filter into a flask. If the washings are turbid pass them again through the filter. Ignite the residue in a platinum crucible, fuse with a little Na_2CO_3, dissolve the melt in HNO_3 and add the solution, if clear, to the main one. If not clear, filter. The fusion of the residue may be dispensed with in routine work on a given coal or coke if it is certain that the residue is free from phosphorus. Add NH_4OH until a slight precipitate ensues. Add concentrated HNO_3 to just dissolve the precipitate, then add 3 to 5 cc. of the acid in excess. Heat the solution, which should have a volume of about 100 cc., to 80° C. and add 50 cc. of molybdate solution. Shake the flask for 10 minutes, filter, and determine the phosphorus as described in Section 22, *Method No. 1.*

PROPOSED NEW TENTATIVE STANDARDS

In the report of Committee D-5 for 1927 were included methods of test under consideration for determination of cubic foot weights and sieve analyses of coke and crushed bituminous coal. The methods of determination of cubic foot weights of coke and crushed bituminous coal and sieve analysis of coke have been approved by Committee D-5 for recommendation as tentative. The method of sieve analysis of crushed bituminous coal has been referred back to Sub-Committee I for further study as to method of sieving.

A method of testing coke, known as the tumbler test, was prepared jointly by a special sub-committee of Sub-Committee I and a Committee on Standardization of Coke Testing Methods of the Eastern States Blast Furnace and Coke Oven Association. This method has been approved by Committee D-5. It is one of the physical tests of coke commonly used in testing coke for blast-furnace use.

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[1] Ullman and Buch, *Chemical Engineer*, Vol. 10, p. 130 (1909).

Committee D-5 recommends that the following proposed methods of test, appended hereto,[1] be accepted for publication as tentative:

Tentative Method of Test for Cubic Foot Weight of Crushed Bituminous Coal;
Tentative Method of Test for Cubic Foot Weight of Coke;
Tentative Method of Test for Sieve Analysis of Coke;
Tentative Method of Tumbler Test for Coke.

The committee has re-elected the present officers to serve for the ensuing term of two years.

The results of the letter ballot of the committee, which consists of 45 members, on the recommendations contained in this report are as follows:

Items	Affirmative	Negative	Not Voting
I. PROPOSED REVISION OF STANDARD			
Standard Method of Laboratory Sampling and Analysis of Coal (D 271 - 27)	36	1	8
II. PROPOSED NEW TENTATIVE STANDARDS			
Tentative Method of Test for Cubic Foot Weight of Coke	40	0	5
Tentative Method of Test for Cubic Foot Weight of Crushed Bituminous Coal	40	0	5
Tentative Method of Test for Sieve Analysis of Coke	40	0	5
Tentative Method of Tumbler Test for Coke	38	0	7

This report has been submitted to letter ballot of the committee, which consists of 45 members; 42 members returned their ballots, of whom 41 have voted affirmatively, none negatively, and 1 has marked his ballot "not voting."

Respectfully submitted on behalf of the committee,

A. C. FIELDNER,
Chairman.

W. A. SELVIG,
Secretary.

H. C. PORTER,
Vice-Chairman.

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[1] See pp. 966–974, respectively.—ED.

EDITORIAL NOTE

The proposed revision of the Standard Method of Laboratory Sampling and Analysis of Coal and Coke was accepted for publication as tentative and appears on page 1129.

The proposed Method of Test for Cubic Foot Weight of Coke; Test for Cubic Foot Weight of Crushed Bituminous Coal; Test for Sieve Analysis of Coke; and Tumbler Test for Coke were accepted for publication as tentative and appear on pages 968, 966, 970 and 973, respectively.

REPORT OF COMMITTEE D-7

ON

TIMBER

Committee D-7 on Timber has the following report to make with reference to its activities during the past year.

Sub-Committee I on Specifications for Timber has considered the standard adopted last year (D 245 – 27) and has no changes to suggest at this time.

Sub-Committee VI on Timber Preservatives this year is recommending the adoption as standard of the Tentative Method of Test for Distillation of Creosote Oil (D 246 – 27 T) as revised in 1927. This sub-committee has during the past year, in cooperation with similar committees of the American Railway Engineering Association and the American Wood Preservers' Association, enlisted the cooperation of the U. S. Bureau of Standards for the purpose of developing a more accurate method for determining expansion factors of creosote oil, and specific gravity and volume correction tables are being prepared by the Bureau. When the tables are adopted by the Society a suitable change will be made in Section 9 of the Standard Methods of Analysis of Creosote Oil (D 38 – 27) to incorporate a reference to the tables in place of the present correction. The sub-committee is furnishing as information in this connection, a review of the methods hitherto used in determining expansion and specific gravities of creosote oils.

Sub-Committee X on Nomenclature and Definitions has developed a list of definitions which has been submitted to Committee E-8 for consideration, and it is expected that these definitions will be submitted as tentative next year.

Sub-Committee XI on Moisture Content of Timber has continued its studies on methods for determining moisture in timber. A progress report on this subject is appended hereto as information.

Committee D-7 makes the following recommendations:

1. The revision of the Tentative Method of Test for Distillation of Creosote Oil (D 246 – 27 T) as indicated in the report of Sub-Committee VI appended hereto and the advancement to standard of the method as revised.

The committee has re-elected the present officers to serve for the ensuing term of two years.

The recommendations appearing in this report have been submitted to letter ballot of the committee with the following results:

Items	Affirmative	Negative	Not Voting
1. Revision of Tentative Method of Test for Distillation of Creosote Oil (D 246 - 27 T)	21	0	5
2. Advancement to standard of Tentative Method of Test for Distillation of Creosote Oil (D 246 - 27 T)	21	0	5

This report has been submitted to letter ballot of the committee, which consists of 26 members; 24 members returned their ballots, of whom 22 have voted affirmatively, none negatively, and 2 have marked their ballots "not voting."

Respectfully submitted on behalf of the committee,

HERMANN VON SCHRENK,
Chairman.

J. A. NEWLIN,
Secretary.

EDITORIAL NOTE

The Tentative Method of Test for Distillation of Creosote Oil was approved at the annual meeting as revised by the committee and subsequently adopted as standard by letter ballot of the Society on September 1, 1928, and appears in the 1928 Supplement to Book of A.S.T.M. Standards.

REPORT OF SUB-COMMITTEE VI ON TIMBER PRESERVATIVES

The cooperative undertaking by the U. S. Bureau of Standards with the Committee on Preservatives of the American Wood Preservers' Association, the Committee on Wood Preservation of the American Railway Engineering Association and this committee to prepare tables for correcting the density and volume of creosote oil from observed temperatures to standard temperature, which was referred to in the report of the sub-committee for 1927, has constituted the principal work of the sub-committee through the past year. As a result of the work the tables are now being prepared by the Bureau of Standards. When the tables are adopted by the Society, a reference to them will be included in the Standard Methods of Sampling and Analysis of Creosote Oil (D 38 – 27) to take the place of the present correction factor.

As these tables will be based on newly determined values appreciably different from the "Correction Factor" from which the tables now used in the wood preserving industry were made, the matter is important enough to warrant giving a brief history of the development of the subject during a quarter century in which the wood preserving industry has at least quadrupled in volume of preservatives used.

The need for a fair degree of accuracy in correcting observed volumes of creosote to a standard temperature of 38° C. (100° F.) is indicated by the fact that the oil is frequently measured in working or storage tanks and in tank cars and steamers, at temperatures ranging from 38 to 100° C.

According to the best information obtainable, the late Dr. H. W. Jayne of Philadelphia was authority for the factor 0.0008 per 1° C. (0.00044 per 1° F.). This factor was published in American Railway Engineering Association *Bulletin No. 65* (1905). Tables based on this factor are still the official standards of the American Railway Engineering Association and the American Wood Preservers' Association, although new figures more nearly approaching the figures finally determined by the Bureau of Standards have come into quite general use in the industry as a result of various independent undertakings in the laboratories of the producing and consuming interests.

It is not known whether Jayne's figure was obtained by tests made in his laboratory or by information from Europe. Possibly the earliest work done in this country was by A. L. Kammerer at St. Louis. Kammerer in 1905 determined a density factor of 0.00075 on creosote from Canada, and later he determined similar figures on Canadian and English creosotes. A few years later when mixtures of tar and creosote came into general use he tested several coke-oven tars and creosote coal-tar solutions, and in 1911 arrived at a working figure of 0.00057 for tar and 0.00070 for an 80-20 solution.

S. R. Church and J. M. Weiss in a report to the American Wood Preservers' Association in 1918 presented results of experiments made in the laboratory of the Barrett Co. on both density determinations and volumetric tests through a temperature range of 15 to 80° C. Three creosotes ranging from light to heavy gave an average correction of 0.00072. In this report it was shown that tests made at a temperature below which the creosote remains perfectly liquid are useless, owing to the large and undeterminable shrinkage that occurs when crystals are being deposited.

TABLE I.—ANALYSIS OF CREOSOTES TESTED BY U. S. BUREAU OF STANDARDS.

	Sample No. 1, Domestic Creosote A.W.P.A. No. 1	Sample No. 2, Domestic Creosote A.W.P.A. No. 2	Sample No. 3, Heavy Distillate Creosote Oil	Sample No. 4, German Anthracene Oil	Sample No. 5, English Creosote Oil	Sample No. 6, Creosote Coal-Tar Solution	Sample No. 7, German Creosote Oil	Sample No. 8, Water-Gas-Tar Creosote Oil	Sample No. 9, Water-Gas-Tar Solution
Specific Gravity at 38° C	1.050	1.042	1.096	1.104	1.050	1.068	1.056	1.020	1.034
Water, per cent	trace	0.5	0.3	0.2	3.5	2.5	3.5	0.5	0.6
DISTILLATION:									
(Method D 246 - 26 T):									
0 to 200° C., per cent	....	....	....	....	1.6	....	1.8	0.8	0.5
0 to 210° C., per cent	0.1	3.6	....	....	3.6	....	3.9	1.4	1.9
0 to 235° C., per cent	12.8	31.1	3.1	....	17.4	8.5	15.2	11.3	13.8
0 to 270° C., per cent	45.3	55.9	20.2	0.6	43.3	40.4	40.5	42.2	41.7
0 to 315° C., per cent	63.5	70.8	37.9	15.1	64.3	61.1	56.8	62.0	58.9
0 to 355° C., per cent	82.9	86.7	61.0	67.2	85.5	74.9	78.7	73.8	72.7

The figures given by Church and Weiss were generally confirmed by E. B. Fulks, Kammerer and others, but the matter did not receive official consideration by the interested committees until 1926 when the undertaking herein reported was commenced.

A joint Conference Committee consisting of W. H. Fulweiler representing the American Society for Testing Materials, Ernest Bateman representing the American Wood Preservers' Association, R. S. Belcher representing the American Railway Engineering Association and S. R. Church, chairman, were placed in charge of this work. Consent of the Director of the Bureau of Standards having been obtained, nine samples of creosote oil collected and tested in the laboratory of the Barrett Co. were sent to the Bureau in October, 1926. Analyses of these oils are given in Table I. Portions of these samples were sent to several members of the three interested committees for the purposes of adding to the general interest of the undertaking and of affording these industrial laboratories an opportunity to check their results against the precise measurements of the Bureau of Standards.

Two of the cooperating laboratories, L. P. Curtin, Western Union Telegraph Co., and L. C. Drefahl, Grasselli Chemical Co., have reported results of their tests, and these are given in Tables II and III. In general, their results are gratifyingly close to the Bureau's measurements.

TABLE II.—RESULTS OF DENSITY DETERMINATIONS BY WESTERN UNION TELEGRAPH CO. ON THE CREOSOTE SAMPLES SUBMITTED BY THE BARRETT CO.

Tests were made by the pyknometer method with temperatures accurate to 0.2° C.

	Density, g. per cu. cm.						
	At 28° C.	At 38° C.	At 48° C.	At 58° C.	At 68° C.	At 78° C.	At 88° C.
Sample No. 1	1.0605	1.0541	1.0465	1.0397	1.0330	1.0222	1.0194
Sample No. 2	1.0514	1.0452	1.0362	1.0308	1.0239	1.0196	1.0087
Sample No. 3	1.1069	1.0999	1.0928	1.0850	1.0788	1.0731	1.0656
Sample No. 4	1.1139	1.1071	1.0993	1.0936	1.0866	1.0791	1.0719
Sample No. 6	1.0780	1.0709	1.0649	1.0573	1.0499	1.0438	1.0369
Sample No. 7	1.0682	1.0604	1.0540	1.0482	1.0413	1.0326	1.0264

TABLE III.—RESULTS OF DENSITY DETERMINATIONS BY GRASSELLI CHEMICAL CO.

The laboratory used the pycnometer method and weighed equal volumes of water and the various oils at the specified temperatures. The weight of water per unit of volume, namely, one centimeter, was taken from standard tables.

	Density, g. per cu. cm.					
	At 32° C.	At 50° C.	At 60° C.	At 70° C.	At 85° C.	Correction per 1° C.
Sample No. 1	1.0581	1.0450	1.0372	1.0297	1.0191	0.0007
Sample No. 2	1.0489	1.0358	1.0292	1.0199	1.0099	0.0007
Sample No. 3	1.1045	1.0912	1.0834	1.0757	1.0660	0.0007
Sample No. 4	1.1111	1.0987	1.0906	1.0845	1.0744	0.0007
Sample No. 5	......	......	......	......	......	No sample
Sample No. 6	1.0757	1.0635	1.0542	1.0480	1.0369	0.0007
Sample No. 7	1.0652	1.0533	1.0466	1.0387	1.0282	0.0007
Sample No. 8	1.0338	1.0211	1.0137	1.0012	0.9964	0.0007
Sample No. 9	1.0456	1.0330	1.0263	1.0177	1.0098	0.0007

During the progress of the work two members of the subcommittee made several visits to the Bureau of Standards for planning the work and discussing the presentation of the results. The most cordial cooperation was extended by the staff of the Bureau of Standards at every point and it seems befitting here, on behalf of this committee, to express its appreciation to the Director of the Bureau of Standards, to Mr. H. W. Bearce, physicist, who was in charge of the work, and to Mr. E. L. Peffer, associate physicist, who carried it out.

The apparatus used by the Bureau for this work consisted of a temperature bath, thermostatically controlled, and platinum-resistance

TABLE IV.—DENSITY DETERMINATIONS MADE BY THE BUREAU OF STANDARDS.

	Density, g. per cu. cm						
	At 40° C.	At 50° C.	At 60° C.	At 70° C.	At 80° C.	At 90° C.	At 100° C.
Sample No. 1. Distillate Creosote Oil	1.05115	1.04367	1.03615	1.02856	1.02096	1.01343	1.00585
	1.05120	1.04368	1.03613	1.02862	1.02106	1.01356	1.00599
	1.05214	1.04466	....	....	....	....	....
	1.05258	1.04513	1.03764	1.03021	....	....	....
	....	....	....	1.03025	1.02279	1.01526	1.00775
	1.05202	1.04453	....	....	....	....	....
	1.05260	1.04513	1.03766	1.03029	....	....	....
	....	....	....	1.03037	1.02290	1.01546	1.00790
Sample No. 2. Distillate Creosote Oil	1.04211	1.03449	....	1.01905	....	1.00343	....
	1.04208	1.03439	....	1.01901	....	1.00343	....
Sample No. 3. Heavy Distillate Creosote Oil	1.09768	1.09033	1.08302	1.07561	....	1.06076	....
	1.09763	1.09026	1.08290	1.07553	....	1.06074	....
Sample No. 4. German Anthracene Oil	1.10450	1.09720	1.09010	1.08292	....	1.06852	....
	1.10471	1.09750	1.09030	1.08311	....	1.06874	....
Sample No. 5. English Creosote Oil	1.05122	1.04364	1.03598	1.02832	....	1.01252	....
	1.05116	1.04351	1.03583	1.02820	....	1.01235	....
	....	....	....	1.02836	....	1.01255	....
Sample No. 6. Creosote Coal-Tar Solution	1.06891	1.06144	1.05398	1.04658	....	1.03144	....
	1.06900	1.06150	1.05404	1.04652	....	1.03168	....
Sample No. 7. German Creosote Oil	1.05844	1.05099	1.04353	1.03584	....	1.02008	....
Sample No. 8. Water-Gas-Tar Creosote Oil	1.01923	1.01182	1.00444	0.99711	....	0.98212	....
	1.01937	1.01199	1.00454	0.99713	....	0.98228	....
Sample No. 9. Water-Gas-Tar Solution	1.03318	1.02589	1.01854	1.01136	....	0.99627	....
	1.03329	1.02595	1.01865	1.01126	....	0.99636	....

TABLE V.—CALCULATED RATE OF CHANGE OF VOLUME AND DENSITY PER 1° C. CHANGE IN TEMPERATURE.

Based upon tests by U. S. Bureau of Standards.

Temperature Range		Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4	Sample No. 5	Sample No. 6	Sample No. 7	Sample No. 8	Sample No. 9
40 to 50° C.	Volume	0.00072	0.00074	0.00067	0.00065	0.00073	0.00070	0.00070	0.00073	0.00071
	Density	0.00075	0.00077	0.00073	0.00072	0.00076	0.00075	0.00074	0.00074	0.00073
50 to 60° C.	Volume	0.00072	....	0.00067	0.00066	0.00074	0.00071	0.00072	0.00073	0.00071
	Density	0.00075	....	0.00073	0.00072	0.00077	0.00075	0.00075	0.00074	0.00073
50 to 70° C.	Volume	....	0.00075	....	....	....	....	....	....	....
	Density	....	0.00077	....	....	....	....	....	....	....
60 to 70° C.	Volume	0.00073	....	0.00069	0.00066	0.00075	0.00071	0.00074	0.00074	0.00072
	Density	0.00075	....	0.00074	0.00072	0.00077	0.00075	0.00077	0.00074	0.00073
70 to 80° C.	Volume	0.00073	....	....	....	....	....	....	....	....
	Density	0.00075	....	....	....	....	....	....	....	....
70 to 90° C.	Volume	....	0.00077	0.00069	0.00067	0.00077	0.00072	0.00077	0.00076	0.00075
	Density	....	0.00078	0.00074	0.00072	0.00079	0.00075	0.00079	0.00075	0.00075
80 to 90° C.	Volume	0.00074	....	....	....	....	....	....	....	....
	Density	0.00075	....	....	....	....	....	....	....	....
90 to 100° C.	Volume	0.00075	....	....	....	....	....	....	....	....
	Density	0.00076	....	....	....	....	....	....	....	....

thermometers for measuring the temperature. The temperature of the bath could be controlled to within 0.005° C. Pyknometers of 100-ml. capacity were used for the density determinations. Results of the Bureau of Standards' tests are shown in Table IV, which gives the density determinations at different temperatures on the nine oils, and Table V, the corresponding rate in change of volume and density per degree change in temperature.

On consideration of the results shown in these tables the Joint Conference Committee made the following recommendations which were subsequently approved by Committee D-7 at a meeting in March, 1928, and have also been approved by the appropriate committees of the American Railway Engineering Association and American Wood Preservers Association:

1. That two kinds of tables should be prepared, one showing the change in volume with temperature and the other showing the change in specific gravity with temperature.

2. In both kinds of tables, one set of tables should be prepared "for coal-tar creosotes and water-gas creosotes having specific gravities at 38 to 15.5° C. lower than 1.0900" and a second set "for high-boiling creosotes or anthracene oil having specific gravities at 38 to 15.5° C. of 1.0900 and above."

These tables will be for use only on distillate oils and not for creosote coal-tar solutions or water-gas-tar solutions. One each of the two latter was included in the oils tested, but this was not considered sufficient on which to base tables. Arrangements have since been made with the Bureau to continue this work by testing a number of representative tars, and this will result in the preparation of additional tables for use with creosote coal-tar solutions.

Attention is directed to the fact that although the tables have a temperature range of 15.5° C. (60.0° F.) to 104.5° C. (220° F.), the values below 40° C. and above 100° C. are not actual but were determined by extrapolation, and further that below 38° C. (100° F.) the correction can be applied only when the oil is liquid at the temperature of observation.

It should be noted that the rate of change of density and of volume is not constant, but increases with increasing temperatures. These tables, therefore, are not the result of using a definite factor, as has been done in the preparation of existing standard creosote tables, but are based on calculated average determinations in each 10° C. temperature range.

The sub-committee recommends that the Tentative Method of

Test for Distillation of Creosote Oil (D 246 - 27 T)[1] be revised as indicated below and that the methods as revised be advanced to standard:

Section 4.—Change the second sentence to read as follows by the addition of the italicized words and the omission of those in brackets:

> The cover (top) may be of transit board *made in two parts, or it may be of* galvanized iron lined with ⅛-in. asbestos [or of other suitable insulating material].

Figure 2.—Change Fig. 2 to show a division of the cover into two semicircular parts, and an opening with a diameter of 27 mm. ± 1 mm.

In the 1926 and 1927 reports the development of this method has been fully set forth. During its two years as a tentative standard no criticism or objection to the new flask has been received, but it has been widely commended. The advancement of this method to standard would thus seem to be indicated.

The sub-committee wishes to correct an error in the Standard Method of Test for Coke Residue of Creosote Oil (D 168 - 27)[2] by changing the word "several" to "seven" in the fourth sentence of Section 2. This is simply the correction of a typographical error.

Respectfully submitted on behalf of the sub-committee,

S. R. CHURCH,
Chairman.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, p. 943 (1926); also 1927 Book of A.S.T.M. Tentative Standards, p. 531.

[2] 1927 Book of A.S.T.M. Standards, Part II, p. 692.

REPORT OF SUB-COMMITTEE XI ON MOISTURE CONTENT OF TIMBER

ACCURATE LABORATORY METHODS

Only a comparatively small amount of work has been done during the past year on accurate laboratory methods of determining moisture contents. Mr. Ernest Bateman of the Forest Products Laboratory has worked toward the development of a distillation apparatus for use, particularly in the cases of woods containing volatile oils, creosote, etc., which ordinarily cause an error in the use of direct drying in an oven. It is similar in principle to the well known xylol method but has the advantage of omitting inflammable liquids.

A sketch of the apparatus is shown in Fig. 1. It consists briefly of a set of chambers enclosed in a temperature regulated oven in which the wood sample is placed. Adjacent to the oven is a condenser through which connecting tubes pass from each chamber to its respective receiving glass and back again to the cylinder. The receiving or measuring glasses are directly below the condenser. The return tube to the drying chamber is provided to facilitate circulation and more rapid drying. A block of wood is placed in the cylinder, the heat turned on and the condenser placed in operation. The air will then circulate through the apparatus by gravity and in so doing will deposit the condensate in the receiving tubes. Not only is the water collected in this way, but also volatile oils such as turpentine accumulate above the water so that the moisture content figure will not include these oils.

The oven is operated at a temperature of 105° C. and ordinary tap water is used for cooling. A sample large enough to give at least 10 g. of water is required to give an accuracy of 1 per cent. Forty-eight hours are required for the test. The sketch shows six cylinders or compartments, but as many may be included as the oven will hold.

The apparatus requires some modification in the way of improvements in design and arrangement, but is otherwise satisfactory.

RAPID METHODS OF MOISTURE DETERMINATION FOR FIELD USE

Electrical Resistance as an Indicator of Moisture Content:

Several attempts to utilize the flow of electric current as an indicator of moisture content have met with more or less success. Under certain conditions it was possible to obtain good results while in other cases it was a failure. Surface films of moisture were particularly bad and threw the readings off completely. Further experiments by A. J. Stamm of the Forest Products Laboratory lead us to believe that the method has good possibilities if the measurements are made under the proper conditions. As a rule, readings taken through a board were not very satisfactory in the presence of appreciable moisture gradients.

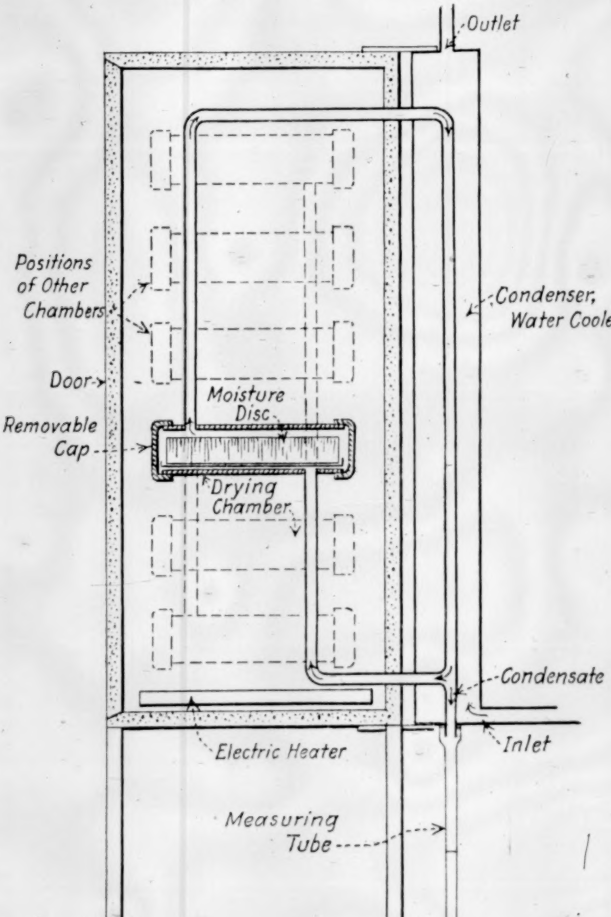
Outlet
Positions of Other Chambers
Condenser, Water Cooled
Door
Moisture Disc
Removable Cap
Drying Chamber
Condensate
Electric Heater
Inlet
Measuring Tube

FIG. 1.—Bateman Distillation Drying Oven.

Tests have indicated that the average moisture content of a board which is dried below the fiber saturation point and in which there is a gradient, lies at a distance of one-sixth of the thickness of the board below the surface. If the moisture content is taken at this point, it fairly represents the average moisture content in the board.

Advantage has been taken of this fact in more recent developments in the measurement of electrical conductivity of wood, and sharp steel points of the proper length are inserted from the same side of the board instead of from opposite sides.

The apparatus is shown in Fig. 2. It consists of a battery (90 volts), galvanometer, a variable shunt, and the insulated block containing the contact points so arranged as to insulate one row of points from the other. If the wood is dry, a low resistance is used on the shunt; if the wood is medium in moisture content, an intermediate resistance is used; and if it is quite moist, a higher resistance is shunted around the galvanometer. Proper scales reading directly in moisture content for each resistance can be made. One hundred and sixty measurements on 25 different kinds of wood ranging in density from 0.340 to 0.705 gave a mean deviation of the observed moisture content from the actual of 0.6 per cent at moisture contents varying from 5.0 to 25 per cent.

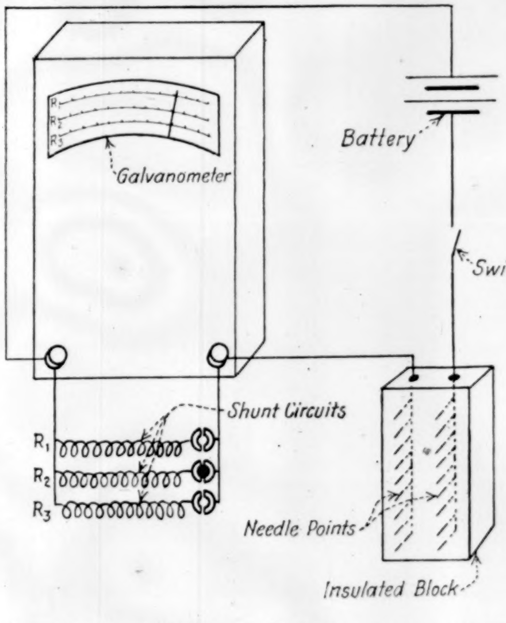

FIG. 2.—Apparatus for Determining the Moisture Content of Wood by Electrical Conductivity.

An apparatus somewhat similar to this has been developed by T. E. Heppenstall of the Long-Bell Lumber Co., Longview, Wash., which is so arranged that it marks wet boards just after they pass over the planer so they can be returned to the kilns for redrying, thus insuring a more uniformly dried and more satisfactory product.

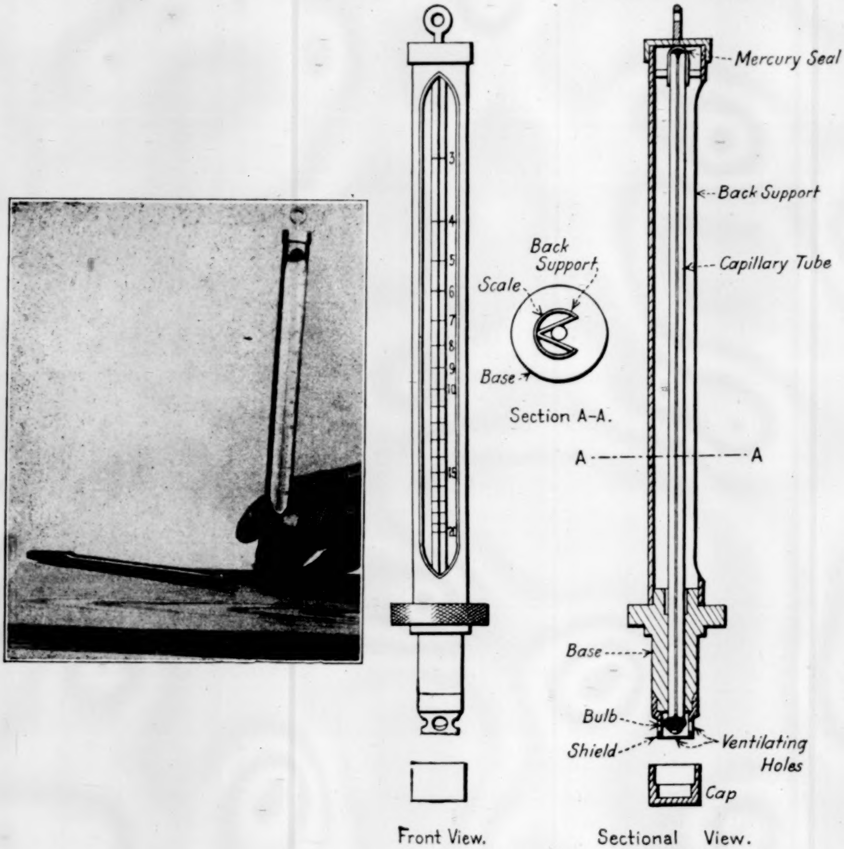
3
4
5
6
7
8
9
10
15
20
Mercury Seal
Back Support
Capillary Tube
Back Support
Scale
Base
Section A-A.
A
A
Base
Bulb
Shield
Ventilating Holes
Cap
Front View.
Sectional View.

FIG. 3.—Wood Hygrometer.

Wood Hygrometer:

The wood hygrometer shown in Fig. 3 is a simple instrument which is being developed at the Forest Products Laboratory as an indicator of moisture in lumber in the field, particularly for inspection purposes. It is simply an indicator of relative humidity, designed in such a way that it will measure the relative humidity in small holes drilled in the wood to be tested. The wood surfaces of the hole humidify the space enclosed, depending upon the moisture content of the wood, because of a fundamental relationship which exists between relative humidity and the moisture content of the wood. The scale for convenience is calibrated in moisture content rather than relative humidity.

TABLE I.—COMPARISON OF MOISTURE CONTENT DETERMINATIONS BY OVEN DRYING AND BY THE WOOD HYGROMETER.

Species	Moisture Content, per cent, based on	
	Oven-dry Weight	Wood Hygrometer
Birch	6.7	6.6
	6.8	6.6
	21.8	25.0
	12.4	11.5
	6.1	6.1
	7.6	7.2
Ash	6.9	6.8
	21.7	26.0
	22.3	23.5
	6.5	6.5
	7.2	6.5
White pine	7.0	6.9
	19.7	25.0
	10.0	9.8
	20.7	21.5
	6.2	6.0
	7.0	6.4
	11.9	12.5
Southern yellow pine	7.7	6.9
	8.3	6.9
	24.2	26.0
	24.0	27.0
Spruce	7.2	6.9
	6.7	6.1
	7.8	6.8
	12.4	12.5
	18.2	21.0
Maple	6.9	6.7
	7.8	7.3
	27.6	23.0
	11.4	9.6
Red gum	7.0	6.7
	7.8	7.2
	11.9	11.1
	6.7	6.0
	12.7	10.9
	24.7	23.0
White Oak	21.8	27.0
	11.3	9.9
	11.6	11.2
	21.7	24.0
	6.8	6.4
	6.5	6.3
	6.6	7.1
Mahogany	7.5	6.7
	21.0	20.8
	7.7	6.8
	7.9	6.4
	11.5	11.5
	6.1	6.3
Cypress	21.9	26.0
	8.4	7.4
	12.6	11.0
	6.7	6.2
Hemlock	12.0	9.8
	12.3	9.8
	7.0	6.4
	8.3	8.1
	8.0	8.7
	5.5	5.6
	5.4	5.3
	10.0	11.0
	10.0	11.5
	16.1	21.5
	15.5	19.2
Cork bark fir	9.5	8.2
	10.0	9.0
	25.8	27.0
	26.1	22.4
	6.0	5.5
	6.3	5.3
	13.8	11.5
	14.0	12.0
Osage Orange	8.6	8.3
	19.3	25.0
	11.1	10.1
	5.9	6.7
Pencil cedar	7.9	7.0
	6.9	6.6
	7.2	6.3
	22.0	22.5
	11.0	10.0
Douglas fir	5.6	6.5
	11.4	10.2
	7.1	7.3
	23.6	25.0
White fir	5.5	6.3
	11.5	10.1
	8.1	7.1
	22.3	24.0
Western yellow pine	27.3	26.0
	5.4	5.8
	5.2	5.8
	11.9	10.9
Yellow poplar	26.4	25.0
	7.2	7.1
	11.5	10.1
	4.9	5.9
Basswood	27.7	25.0
	5.9	6.8
	10.5	10.6
	4.7	6.3
Redwood	20.0	24.0
	5.9	6.4
	10.1	10.2
	6.7	6.6

The apparatus consists briefly of a short piece of capillary tubing to the bottom of which is attached a bag of goldbeater's skin containing mercury. At the top of the column is a mercury seal which permits the passage of air but restrains the flow of mercury. It is necessary to have atmospheric pressure at both ends of the column because of the delicacy of the membrane.

The membrane containing the mercury is a very thin animal tissue which is hygroscopic and changes shape with variations in humidity. When the instrument is placed under definite humidity conditions it quickly responds indicating the moisture content corresponding to these conditions.

The instrument is illustrated in Fig. 3. At the left is shown a multiple spur bit which is convenient for drilling holes, particularly in thin wood.

Table I shows the results of a number of tests with different species and different moisture contents. The results in the majority of cases check the oven-dry weights with sufficient accuracy. The most serious errors shown occur at high moisture contents (above 20 per cent). This indicates that the instrument may be used to determine the moisture content of different species within reasonable accuracy for field observations.

TABLE II.—READINGS OF WOOD HYGROMETER TAKEN AT VARIOUS TEMPERATURES COMPARED TO MOISTURE CONTENTS BASED ON OVEN-DRY WEIGHTS.

Temperature, deg. Fahr.	Moisture Content of White Pine, per cent, based on		Temperature, deg. Fahr.	Moisture Content of White Pine, per cent, based on		Temperature, deg. Fahr.	Moisture Content of White Pine, per cent, based on	
	Oven-dry Weight	Wood Hygrometer		Oven-dry Weight	Wood Hygrometer		Oven-dry Weight	Wood Hygrometer
9	5.5	7.9	11	5.4	6.4	27	5.4	7.5
	10.2	9.3		9.9	7.9		10.2	10.6
	13.2	11.4		13.0	11.6		11.1	10.5
	20.3	16.5		19.2	17.5		21.7	18.0
10	5.6	6.6	13	10.4	10.2	41	4.9	5.3
	5.5	7.0		10.1	10.8		10.0	10.2
	10.3	10.5		13.3	14.0		9.4	9.7
	10.1	10.4		21.1	20.0		20.2	20.0
	11.7	9.8						
	12.3	12.0	26	6.1	7.5	44	4.8	5.5
	21.8	20.2		9.7	10.0		9.3	9.4
	20.4	19.5		14.3	15.0		10.4	12.2
				20.6	22.0		21.0	20.0
							20.1	21.0

Some results of cold weather tests are shown in Table II. Tests were conducted at several different temperatures ranging from 9 to 44° F. The results show reasonable accuracy at these temperatures. There are several precautions required, however. The instrument must be allowed to cool to outside temperature before it can be used and it should be left longer in the wood before reading when the weather is cold. There is apparently a compensating action with regard to temperature between the expansion of the goldbeater's skin and the mercury so that temperature does not affect the instrument greatly.

A series of tests, the results of which are shown in Table III, indicate that the instrument can be used in the sunlight without danger of serious error in the majority of cases. Out of 18 tests shown, three show errors greater than 1 per cent.

TABLE III.—READINGS OF WOOD HYGROMETER TAKEN AT SUMMER TEMPERATURES IN THE SHADE AND IN SUNLIGHT COMPARED TO MOISTURE CONTENT BASED ON OVEN-DRY WEIGHT.

Temperature, deg. Fahr.	Moisture Content of White Pine, per cent, based on		Remarks
	Oven-dry Weight	Wood Hygrometer	
80.5	5.5	4.9	Hygrometer reading taken in shade
	5.5	4.9	
84.7	5.5	4.9	Hygrometer reading taken in sunlight
	5.5	5.0	
80.5	9.7	8.4	Hygrometer reading taken in shade
	9.7	9.0	
84.5	9.7	8.8	Hygrometer reading taken in sunlight
	9.7	9.3	
80.5	9.7	9.7	Hygrometer reading taken in shade
	9.7	10.6	
84.5	9.7	9.8	Hygrometer reading taken in sunlight
	9.7	10.3	
60.8	19.1	19.5	Hygrometer reading taken in shade
	19.1	20.0	
73.3	19.1	15.0	Hygrometer reading taken in sunlight
	19.1	18.5	
60.5	19.1	17.0	Hygrometer reading taken in shade
	19.1	19.0	

A group of wood hygrometers has been constructed and distributed to various interested cooperators in the lumber industry for field trials. The performance of these instruments will be carefully watched in order that their durability and accuracy may be determined in field use.

Respectfully submitted on behalf of the sub-committee,

M. E. DUNLAP,
Chairman.

REPORT OF COMMITTEE D-8
ON
BITUMINOUS WATERPROOFING AND ROOFING MATERIALS

Committee D-8 has held three meetings during the past year. Two of its sub-committees, namely, Sub-Committee IV on Specifications (Including Analytical Methods) for Membrane Materials and Sub-Committee VI on Methods of Fiber Analysis have conducted a considerable amount of work which will ultimately lead to the recommendations of new specifications and methods of tests, but it is felt this work is not in such shape as to justify the committee in making definite recommendations this year. It has recently formed a new Sub-Committee VII on Refined Ductility Tests for Roofing Materials with Mr. Lester Kirschbraun as chairman. At a meeting on March 22 it re-elected for the next two years the present officers.

The committee is not recommending for advancement to standard the Tentative Specifications for Acid-Resisting Asphalt Mastic (D 223 – 25 T), which have been tentative for over two years, and feels that in view of new developments in the art, these specifications should be held as tentative for at least one more year. One tentative method of test is recommended for advancement to standard.

PROPOSED CHANGES IN EXISTING STANDARD SPECIFICATIONS

Standard Specifications for Slate-Surfaced Asphalt Roll-Roofing and Slate-Surfaced Asphalt Shingles (D 225–27).—The attention of the committee has been called to the fact that the term "Slate-Surfaced" in the title of these specifications is a misnomer and for this reason it is recommended that the title be changed to read as follows:

> Standard Specifications for Asphalt Roll-Roofing and Asphalt Shingles Surfaced with Mineral Granules.

Standard Specifications for Heavy Weight Slate-Surfaced Asphalt Roll-Roofing and Heavy Weight Slate-Surfaced Asphalt Shingles (D 249–27).—For reasons above mentioned it is recommended that the title of these specifications be changed to read as follows:

> Standard Specifications for Heavy Weight Asphalt Roll-Roofing and Heavy Weight Asphalt Shingles Surfaced with Mineral Granules.

Standard Methods of Testing Asphalt Roll-Roofing Surfaced with Fine or Granular Talc, Slate-Surfaced Asphalt Roll-Roofing and Slate-Surfaced Asphalt Shingles (D 228-27).—For reasons above mentioned it is recommended that the title of these standard methods be changed to read as follows:

> Standard Methods of Testing Asphalt Roll-Roofing Surfaced with Fine Talc, Granular Talc, or Mineral Granules, likewise Asphalt Shingles Surfaced with Mineral Granules.

It is further recommended that in all the standards reference to "Slate Surfaced" be changed to accord with changes in title.

PROPOSED ADVANCEMENT TO STANDARD OF EXISTING TENTATIVE METHOD OF TEST

Tentative Method of Test for Steam Distillation of Bituminous Protective Coatings (D 255-26 T).[1]—No criticisms have been received of this method of test during the past year and the committee feels that it is in satisfactory form. It is therefore recommended that this tentative method of test be advanced to standard.

The results of letter ballot of the committee upon the recommendations made in this report are given in the following table:

Items	Affirmative	Negative	Not Voting
I. PROPOSED ADVANCEMENT OF TENTATIVE METHOD OF TEST TO STANDARD			
Tentative Method of Test for Steam Distillation of Bituminous Protective Coatings (D 255 - 26 T)........	34	3	13

This report has been submitted to letter ballot of the committee, which consists of 50 members; 42 members returned their ballots, of whom 40 have voted affirmatively, none negatively, and 2 have marked their ballots "not voting."

Respectfully submitted on behalf of the committee,

S. T. WAGNER,
Chairman.

PRÉVOST HUBBARD,
Secretary.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, p. 998 (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 553.

EDITORIAL NOTE

The Tentative Method of Test for Steam Distillation of Bituminous Protective Coatings was approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on September 1, 1928, and appears in the 1928 Supplement to Book of A.S.T.M. Standards.

REPORT OF COMMITTEE D-9
ON
ELECTRICAL INSULATING MATERIALS

Three meetings, each of two days, have been held by the committee and its sub-committees during the year, in addition to the one held during the annual meeting of the Society. The meetings held were as follows:

At Hotel Sagamore, Rochester, N. Y., October 27 and 28, 1927;
At the Engineering Societies Building, New York City, February 2 and 3, 1928; and
Wardman Park Hotel and U. S. Bureau of Standards, Washington, D. C., April 19 and 20, 1928.

The sub-committees have found that their work is greatly facilitated by having additional meetings at times other than those at which the main committee holds its meetings. Sub-Committee II on Molded Insulating Materials and Sub-Committee III on Sheet Insulating Materials have been particularly active in this respect during the past year. The activities of the committee have been devoted to the development of new methods of testing insulating materials and to the improvement of methods now being used as tentative or standard.

EXISTING STANDARDS AND TENTATIVE STANDARDS

Standard Methods of Testing Molded Insulating Materials (D 48 - 27):[1]

For some time a rather extensive study has been under way as to the possible improvement of the tension test specimen for molded materials. The statements made in last year's report as to the shape of the tension test specimen seem to have been verified, and after careful study a recommendation is being made for a new test specimen which is to be applicable to hot molding compounds, shellac compounds, pitch molding compounds, but not to silicate cold-molded compounds.

The committee recommends the following revisions of these methods:

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 785.

Section 2.—Change from its present form: namely,

2. Any standard testing machine may be used provided the error in the loading range does not exceed 1 per cent. Special clips (see Fig. 1) of hardened steel shall be used, hung from links held in the jaws of the machine, so that the pull is central at all times, to avoid any transverse strain.

to read as follows:

2. Any standard testing machine may be used provided it is accurate to within 1 per cent of the lowest load to be applied. Special specimen holders of steel, as shown by Fig. 1 (*a*), shall be used. The specimen holders shall be attached to the heads of the machine by links held so that the pull is central to avoid any transverse strain.

Section 3.—Change from its present form: namely,

3. The standard test specimen shown in Fig. 1 shall be used for the tension tests. It shall be molded to the dimensions shown in Fig. 1.

to read as follows:

3. For hot-molded materials and for plastic cold-molded materials (see Note 1), the test specimen shall be molded to the form and dimensions shown in Fig. 1 (*b*).

NOTE 1.—Due to wide differences in molding characteristics, the specimen suited to hot-molded and plastic cold-molded materials is unsuited to the non-plastic inorganic cold-molded materials. A specimen suitable for these latter compounds is now under consideration:

Section 4 (*b*).—Omit the last sentence of this section, reading as follows:

Measurements may be taken at intervals during the test to show the elongation of the specimen when required for elastic materials.

Section 5.—Change Paragraph (*b*) to read as follows by the addition of the italicized words:

(*b*) The thickness *and width* of each specimen in inches or millimeters as measured by a micrometer at the center of the specimen, that is, the point of minimum section;

Change Paragraph (*d*) from its present form: namely,

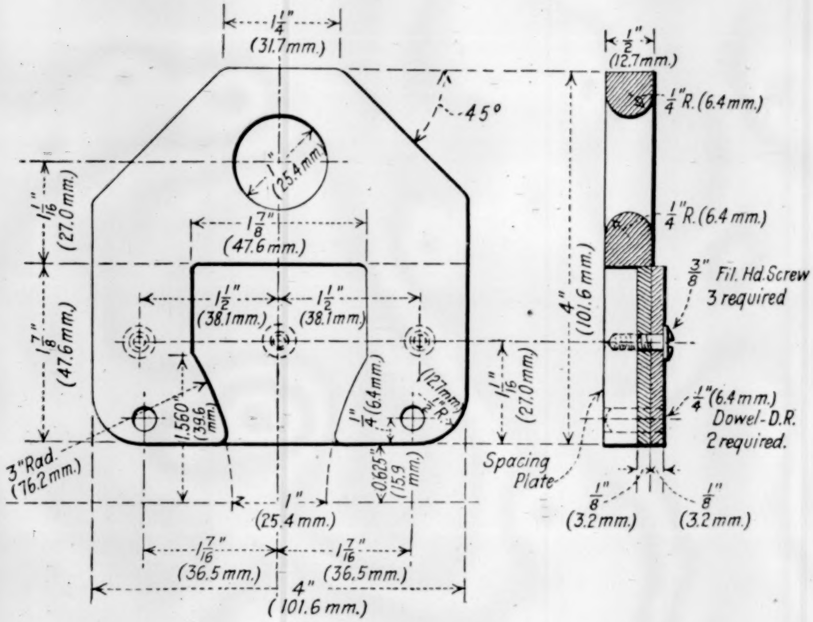
(*d*) The character of the material tested, with description of how it acts under stress;

to read as follows:

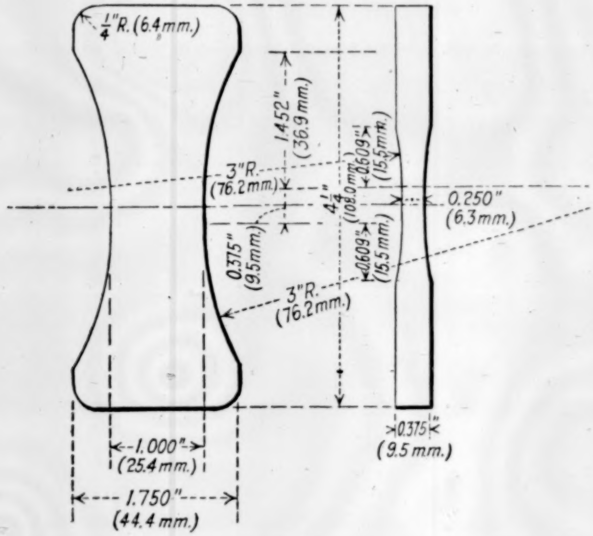
(*d*) The character of the material tested, with a description of the fracture and its location with respect to the middle point of the specimen;

Change Paragraph (*e*) to read as follows by the addition of the italicized words and the omission of the word in brackets:

(*e*) The speed in inches or millimeters per minute at which the [jaws] *head of the testing machine* traveled during the test.


1 1/4" (31.7 mm.)
45°
1" (25.4 mm.)
1 1/16" (27.0 mm.)
1 7/8" (47.6 mm.)
1 1/2" (38.1 mm.)
1 1/2" (38.1 mm.)
1 7/8" (47.6 mm.)
1.560" (39.6 mm.)
1/4" (6.4 mm.)
(12.7 mm) 1/2" R
3" Rad. (76.2 mm.)
0.625" (15.9 mm.)
1" (25.4 mm.)
1 7/16" (36.5 mm.)
1 7/16" (36.5 mm.)
4" (101.6 mm.)
1 1/16" (27.0 mm)
4" (101.6 mm.)
Spacing Plate
1/2" (12.7 mm.)
1/4" R. (6.4 mm.)
1/4" R. (6.4 mm.)
3/8" Fil. Hd. Screw 3 required
1/4" (6.4 mm.) Dowel-D.R. 2 required.
1/8" (3.2 mm.)
1/8" (3.2 mm.)

(*a*) Specimen holder.


1/4" R. (6.4 mm.)
1.452" (36.9 mm.)
3" R. (76.2 mm.)
4 1/4" (108.0 mm.)
0.609" (15.5 mm.)
0.250" (6.3 mm.)
0.375" (9.5 mm.)
0.609" (15.5 mm.)
3" R. (76.2 mm.)
0.375" (9.5 mm.)
1.000" (25.4 mm.)
1.750" (44.4 mm.)

(*b*) Tension test specimen.

FIG. 1.—Tension Test Specimen and Holder.

Figure 1.—Replace the present figure showing the tension test specimen with a new figure conforming to the accompanying Figs. 1 (*a*) and (*b*).

The present tentative revisions of these methods[1] are recommended to be continued as tentative without change.

Tentative Methods of Testing Insulating Varnishes (D 115 – 26 T):[2]

There has been a demand for some time for an accurate test to determine the volume percentage of volatile matter, or solvent, in an insulating varnish. In order to meet this demand a test entitled "Test for Volatile Matter by Volume," has been developed, as appended to this report[3] and is recommended by the committee to be added to the Tentative Methods of Testing Insulating Varnishes (D 115 – 26 T) as Sections 27 to 32, inclusive.

For some time the committee has been making studies of the "Dielectric Strength of Varnish in the Liquid State." There seems to be a demand for such a test which can be used to evaluate shipments of varnish with respect to the presence of moisture, dirt, or other contamination. It is therefore recommended that the Method of Testing Dielectric Strength of Varnish in the Liquid State as appended to this report[3] be added to the present Tentative Methods of Testing Insulating Varnishes (D 115 – 26 T) as Sections 33 to 37, inclusive.

Tentative Methods of Testing Electrical Porcelain (D 116 – 27 T):[4]

The studies on porcelain during the past year have been devoted largely to the development of a suitable test for the determination of resistance to impact. The method adopted for this determination is known as the "Simple Beam Method" and is described in detail in the revisions being proposed this year of Methods D 256 – 26 T. This revision is described elsewhere in this report. The method supersedes the one now described in Methods D 116 – 27 T. In order to include this new method for the resistance to impact the committee recommends the following revisions in Methods D 116 – 27 T:

Section 18.—Change from its present form: namely,

18. The test shall be made with an apparatus in which a weight of 1 lb. is raised ½ in. and allowed to fall on the specimen. It is then raised 1 in. and

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 1099 (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 773.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, p. 1002 (1926); also 1927 Book of A.S.T.M. Tentative Standards, p. 569.

[3] These new methods of test have been incorporated in the Tentative Methods of Testing Insulating Varnishes, see p. 975.—ED.

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 981 (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 577.

allowed to fall again on the specimen. This is continued, the weight being raised and dropped through a distance increasing by increments of ½ in. until the specimen is broken.

to read as follows:

18. Resistance to impact shall be determined in accordance with the Tentative Methods of Testing Insulating Materials for Resistance to Impact (Serial Designation: D 256 - 28 T of the American Society for Testing Materials, using the "Simple Beam Method").

Omit the present Sections 19, 20 and 21, comprising the description of the impact test including Fig. 5 referred to in that description, and change the numbering of the present Sections 22 to 43, inclusive to Sections 19 to 40, inclusive. Change the numbering of the figures so that the present Fig. 6 will become Fig. 5 and the present Fig. 7 will become Fig. 6 and make all references agree with the new numbering.

Tentative Methods of Testing Electrical Insulating Materials for Voltage Effects at Radio Frequencies (D 175 - 25 T):[1]

The committee, having canvassed the situation relative to the utility of Methods D 175 - 25 T, which have been tentative for three years, finds that they are not being used in this country. The investigation developed that there is a need for tests of this character, but it is felt that the present methods cannot be so modified as to be satisfactory. The committee accordingly concluded that it is best to withdraw these methods and take up the development of more promising methods.

The withdrawal of Methods D 175 - 25 T is recommended.

Tentative Methods of Testing Untreated Insulating Papers (D 202 - 27 T):[2]

The committee recommends the following minor changes in wording of these methods:

Section 12 (a).—Change from its present form: namely,

12. (*a*) A testing machine suitably designed for testing paper shall be used. The machine shall preferably be power driven.

to read as follows:

12. (*a*) A testing machine of the dead weight pendulum type suitably designed for testing paper shall be used. The machine shall preferably be power driven.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 25, Part I, p. 804 (1925); also 1927 Book of A.S.T.M. Tentative Standards, p. 609.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 1013 (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 620.

Section 18.—Insert a new sentence immediately following the first sentence of the section to read as follows:

> The specimens shall be so arranged that an equal number of tears originating from opposite edges of the specimens will be produced.

Tentative Methods of Testing Laminated Sheet Insulating Materials (D 229 - 26 T):[1]

The studies during the year which have led to definite recommendations have been on transverse strength, compressive strength and water absorption. The committee recommends the following changes and new test procedures:

Change the title of "Transverse Strength" to "Flexural Strength" so as to correspond to the nomenclature recommended by Committee E-1 on Methods of Testing.

Change the subtitle from its present form: namely,

> (*A*) *For Materials ½ in. Thick or Over.*[a]

to read as follows:

> (*A*) *For Materials ⅛ in. Thick or Over.*[b]

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[a] A method of test for thinner material is being considered.

[b] Conventional flexure tests in a flatwise direction are not recommended for materials thinner than ⅛ in. nor in the edgewise direction for materials thinner than ½ in.

Section 11 (b).—Change from its present form: namely,

> (*b*) The distance between points of support shall be 4 in. for specimens ½ in. in thickness and proportionately longer for greater thicknesses. The supports shall have the contact edges rounded to a radius of ⅛ in. The load shall be applied midway between the supports by a pressure piece, the bearing edge of which shall be rounded to a radius of ⅛ in.

to read as follows:

> (*b*) The specimen shall be tested as a simple beam loaded at the center. The supports shall have contact edges rounded to a radius of ⅛ in. The load shall be applied midway between the supports by a pressure piece, the bearing edge of which shall be rounded to a radius of ⅛ in. The distance between the points of support shall be 4 in. for edgewise tests of all thicknesses and eight times the nominal thickness of the material to be tested for tests in the flatwise direction.

Section 12.—Change from its present form: namely,

> 12. The test specimen shall be 5 in. in length, ½ in. in width and ½ in. in thickness, for sheets ½ in. in thickness and for thicker sheets it shall be the full thickness of the sheet with width and length increased in proportion.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, p. 1052 (1926); also 1927 Book of A.S.T.M. Tentative Standards, p. 635.

to read as follows:

> 12. The test specimen shall be ½ in. in width except for specimens over ½ in. in thickness tested in the flatwise direction, which shall have the width equal to the thickness of the specimen. The thickness shall be the full thickness of the sheet. The length shall be 1 in. greater than the distance between the points of support as specified in Section 11 (*b*).

Compressive Strength.—The subject of compressive strength of laminated material has been studied for some time and the committee recommends a procedure for conducting the compressive strength test, as appended to this report,[1] be added to the Tentative Methods of Testing Laminated Sheet Insulating Materials (D 229 - 26 T), as Sections 17 to 21, inclusive.

Water Absorption.—The use of water absorption tests for laminated materials in the industry has become quite common practice. A uniform method of making this test has seemed desirable in order that different persons using the test can obtain comparable data. The proposed test is a result of the efforts along this line. The committee therefore recommends the inclusion of the water absorption test for laminated sheet insulating materials, as appended to this report,[1] as Sections 22 to 31, inclusive, of the Tentative Methods of Testing Laminated Sheet Insulating Materials (D 229-26 T). Change the present Sections 17 and 18, referring to the dielectric strength test and test for phase difference and dielectric constant to Sections 32 and 33.

Tentative Methods of Testing Insulating Materials for Resistance to Impact (D 256 - 26 T):[2]

During the year Methods D 256 have been completely rewritten and have been broadened in their scope to include ceramic and laminated materials in addition to molded materials for which they were originally developed. The committee recommends the withdrawal of the present Tentative Methods of Testing Insulating Materials for Resistance to Impact (D 256 - 26 T) to be superseded by the proposed Tentative Methods of Testing Insulating Materials for Resistance to Impact appended hereto.[3]

NEW TENTATIVE STANDARDS

Varnished Cloth Tapes:

There has been a frequent demand of late for standard methods for the testing of varnished cloth tapes as numerous purchase specifications are in use which set up standards of quality without including any description of test methods. More than a year ago a section was formed to investigate the situation. Its activities have included the study of existing test methods and experimental work in the development of such additional methods as appeared to be required.

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[1] These new methods of test have been incorporated in the Tentative Methods of Testing Laminated Sheet Insulating Materials, see p. 1013.—ED.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, p. 1056 (1926); also 1927 Book of A.S.T.M. Tentative Standards, p. 639.

[3] See p. 1021.—ED.

As the result of this detailed study it is recommended that the proposed Methods of Testing Varnished Cloth Tapes be accepted for publication as tentative as appended hereto.[1]

MISCELLANEOUS

Insulating Varnishes:

The work on the development or selection of a better method for the determination of the drying time of varnishes, referred to in the report of the committee for 1927, has been continued. While the General Electric Co. and British Electric and Allied Industrial Research Association methods have given closer agreement between laboratories, our present copper base method (Sections 5 to 7 of Methods D 115 - 26 T) has proved a more sensitive test.

The result of further studies using modifications of the General Electric Co. and E. R. A. methods seems to indicate: that one coat of varnish on specimens is as satisfactory as two; that copper is a better base than bond paper; that Kraft paper is preferable to Whatmans filter paper; that the E. R. A. method has the advantage of being mechanical and removing the personal element from the test. These studies are being continued.

Other varnish problems now under consideration are the development of methods for determination of hardness of varnish films and acid and alkali resistance of varnish films.

Molded Insulating Materials:

The studies outlined in last year's report have led to definite recommendations, as given earlier in this report, on the impact test and tension test specimen for molded materials. The impact test has been extended so as to be more explicit in its instructions and so as to include ceramic and laminated materials. The proposed tension test specimen shows a marked improvement over the old figure-eight as applied to hot molded, shellac, and cold mold pitch compounds, but not to cold mold silicate compounds.

The question of the effect of the notch in the Charpy specimen on the impact strength is receiving consideration. Since a notch represents a condition that is often found to a certain extent in commercial samples, an attempt will be made to correlate data from the impact sample with actual shop experience. The effect on impact strength of the energy required to carry off the broken part after breakage occurs is also under investigation. So far the results indicate that any corrections to be made depend upon complex factors involving relationships possibly between the mass, the resilience, and the strength of the specimen. Whether such corrections can conveniently be made will depend upon the results of further studies.

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[1] See p. 1026.—ED.

The study of test methods for water absorption referred to in last year's report has been continued. To obtain comparative data, tests have been made on numerous samples to determine the practicability of working out the relation between water absorbed and surface per unit volume or mass. Another question that arises is concerned with the comparison of water absorbed in a humid atmosphere with that absorbed when the specimen is immersed in water. It is hoped that these studies will lead to an improved water absorption test for molded materials.

The development of a plasticity or "flow" test for hot molded materials is being taken up by the committee. The test is desired by users of hot molding compounds to insure the selection of materials of definite molding characteristics and to act as a guide in handling the materials in the regular molding operations.

Sheet Insulating Materials:

Insulating Paper.—Some difficulty has been experienced in obtaining consistent tensile strength results with some of the different testing machines.

When tearing paper samples away from the surface which was next to the paper machine felt, a different value was obtained for the tearing strength than when torn in the opposite direction. The difference in results was as much as 7 to 13 per cent. These studies have resulted in changes in Methods D 202 - 27 T as recommended earlier in this report.

A new oil saturation test has been developed which is being used to determine the effect of fiber length and surface finish on the saturating properties of paper.

Further work is in progress on the revision of the method of gaging paper with especial reference to tissue paper.

The present pendulum impulse type of tear testing machine does not seem well suited to testing some kinds of paper which have relatively great resistance to initial tearing but which tear relatively easy once the tear is started. A new method is being studied to determine the initial tearing strength.

Arrangements have been made with the Paper Testing Committee of the Technical Association of the Pulp and Paper Industry for cooperative work through one of our members who is also a member of that committee.

Laminated Sheets.—As noted earlier in this report, recommendations have been made on transverse strength, compressive strength, and water absorption tests for laminated materials. Further work will be carried on in connection with flexure tests for thin materials as mentioned in last year's report.

Deterioration.—Further study of causes of deterioration of insulating materials which has been referred to in previous reports has led the committee to begin its investigation of test methods by the study of suitable equipment for heat treating sheet insulating materials.

Thermal Conductivity.—The measurements of the thermal conductivity of samples of graphite-rubber composition of different proportions referred to in last year's report have been completed by three laboratories. The results indicate that thermal resistivity can be fairly well predicted from the percentage of graphite present. This will be of importance in establishing standards of thermal conductivity.

Varnished Cloth Tapes.—In last year's report attention was called to the proposed development of methods for testing varnished cloth tapes. This work has been completed and has resulted in the proposed Tentative Methods of Testing Varnished Cloth Tapes referred to earlier in this report.

Liquid Insulation:

The work on liquid insulation has been very active during the year on investigations which have been divided under four general headings: (*a*) Neutralization Number; (*b*) Life Test; (*c*) Short Time Sludging Tests; and (*d*) Stability Test for Cable Compounds.

(*a*) *Neutralization Number.*—During the year, studies have been made along two principal lines (1) the development of a suitable electrometric method for measuring the neutralization of oil and (2) the correlation of neutralization values with other properties of the oils. In connection with the latter, progress has been made in developing a method for determining the solubility of water in oils.

(*b*) *Life Test.*—The results of an extensive series of cooperative tests in connection with the study of the effect of very small amounts of contamination as it affects the life test have indicated that, possibly as a general acceptance test, the life test as it now stands may be too sensitive. The sub-committee has consequently decided to study. during the coming year, the possibility of modifying the test by lowering the temperature and introducing a catalyst such as copper.

Several problems in relation to the life test have been investigated during the year. Briefly, the results of this study have resulted in determining:

1. That oils which give the longest life test do not always show the slowest rate of sludge formation after sludging starts;
2. In general, vapors from oils with poor life test do not contaminate, in the same run, oils having good life test.
3. Freshly formed iron oxide in a very finely divided form lowers the life test of oils markedly.
4. The rate of centrifuging of the sample removed from the life test for observation has no appreciable effect on the test, a difference of 12½ to 21 in. in length of centrifuge arms making a difference of about one day in the test.
5. Short exposure to light (one day or less) greatly reduces the life test of an oil. Exposure to direct sunlight accelerates this effect.
6. Good life oil when placed into a new transformer may have its life test very appreciably lowered after being in the transformer but a few hours, even though the transformer is not energized. A very slight contamination from insulating varnishes or other sources seems to give an initial rate increase in sludge formation on the life test out of all proportion to the magnitude of the contamination.

Other investigations on insulating oils have included work on short time sludging tests; free sulfur in circuit breaker oils; and water retentivity tests.

A large amount of cooperative testing, particularly as regards sludge tests has been carried on in cooperation with the United States Committee of the International Electrotechnical Commission with which committee Committee D-9 has considerable overlapping of membership.

The I. E. C. Standard for Sampling Insulating Oil has been referred to this committee and is now being studied preliminary to making recommendations for modifications or approval.

The committee is studying the matter of developing a more satisfactory method of sampling oils in service in circuit breakers and transformers.

There has been prepared by A. E. Flowers of the sub-committee a summary of oxidation tests for evaluating insulating oils which as a useful table of reference is reproduced in the accompanying Table I.

TABLE I.—SUMMARY OF OXIDATION TESTS FOR EVALUATING INSULATING OILS.

Name of Test	Size of Sample	Container	Temperature of Test, deg. Cent.	Duration of Test, hours	Air or Oxygen	Rate of Admission of Air or Oxygen	Catalysts Used	Criterion for Evaluating the Oil
French	Approximately 10 to 12 g.	15 mm. by 150 to 160-mm. test tubes	150	5, 50 and 135	Air	Surface exposure	None	Weight of sludge formed and discoloration of oil.
Belgian	40 cc.	Test tubes, 50 mm. inside diameter, 37 mm. long	200	10	Air	Surface exposure	None	Weight of sludge formed.
English (Michie)	100 cc.	Glass container	150	45	Air	2 liters per hour	Copper	Weight of sludge formed.
German (Tar Forming No.)	150 g.	300-cc. Erlenmeyer flask	120	70	Oxygen	2 bubbles per second through a tube of 3 mm. diameter	None	Weight of material extracted by caustic soda solution.
Italian	40 g.	Test tubes, 25 mm. diameter, 190 mm. long	110	300	Air	Surface exposure	2 g. (400 sq. cm.) copper wire gauze of given mesh	Acid number and weight of sludge formed. Effect on tensile strength of cotton.
Swiss (BBC Test)	1000 cc.	Copper vessel	115	168 and 336	Air	Surface exposure	See heading "Container"	Acid number of oil and volume of sludge formed with normal benzine. Effect on immersed cotton fibres.
American (Life Test—Snyder)	500 cc.	600-cc. glass beakers	120	See "Criterion"	Air	Surface exposure	None	Length of time required for sludge formation to occur.
Waters' Carbonization	10 g.	200-cc. Erlenmeyer flasks	250	2.5	Air	Surface exposure	None	Weight of sludge precipitated with petroleum ether.
Sligh Oxidation	10 g.	Special closed glass flasks	200	2.5	Oxygen	Surface exposure	None	Weight of sludge precipitated with petroleum ether.
Standard Method of Staatliche Prüfungs Anstalt	100 cc.	200-cc. round bottom flask equipped with an air condenser	120	70	Oxygen	2 liters per hour	Copper cylinder (32 by 51 by 0.1 mm.)	Weight of sludge precipitated with standard benzine, plus residue sticking in flask.
Formolite No.	21.5 g.	500-cc. flask with 40-cc. petroleum ether	Ice bath	10 cc. formaldehyde and 10 cc. concentrated sulfuric acid added under specified condititions				Weight of precipitate from preceding reaction.
Sweden (Anderson—ASEA)	60 g.	Special cell of metal and glass	100	70, 100 and 200	Oxygen	1 liter per hour through a silver-plated copper tube, 4 mm. diameter	Copper and iron plus a field of 10 kv. per cm.	Acidities of oil and sludge. Weight of sludge formed.
Sweden (Standard)	1000 cc.	Glass container	120	70	Oxygen	Surface exposure	None	Weight of tar formed. Clearness of oil.

Porcelain Insulation:

The work on impact which was being studied last year has been continued and the method adopted is that described in the revised Methods D 256 being submitted this year, using the simple beam method.

Cable Splicing and Pothead Compounds:

Materials used as jointing compounds for high-voltage cables have undergone considerable change during the past few years with a tendency toward the use of liquid compounds. Consequently the point of emphasis has shifted, calling for changes in test methods to render them applicable to the more commonly used materials. The committee is continuing the study of this problem.

Radio Frequency Tests:

Consideration is being given to the possibility of doing work at short wave lengths, such as 15 to 30 meters, with the following laboratories participating: Bakelite Corporation, General Electric Co., Westinghouse Electric and Manufacturing Co., and the Naval Research Laboratory. The results so far obtained are promising. The Bakelite Laboratory has found fairly good agreement for some materials between the values at one million cycles and at 17 million cycles and is now making important improvements in apparatus used. The Naval Research Laboratory is attempting to measure the losses by noting the resistance necessary to stop and start oscillations in a Colpits circuit containing resistance, inductance, and capacitance, and the constants of the tube in the circuit.

Methods of Measurement of Resistivity and Power Factor:

During the year there was organized a sub-committee to prepare methods for testing the resistivity, power factor, and dielectric constant of insulating materials. This committee has prepared definitions of resistivity, power factor, and dielectric constant and has collected information concerning test methods now in use. The most urgent problem appears to be the preparation of a standard method for measuring the resistivity of liquid insulation. Data are now being collected to determine the essential factors which must be specified in any standard method for measuring the resistivity of a liquid.

The various methods now in use will be checked by distributing to several laboratories samples of materials having power factors of different magnitudes.

The committee has re-elected the present officers to serve for the ensuing term of two years.

The following is the result of the letter ballot vote of the committee, which consists of 52 members, on the recommendations made in this report:

Items	Affirmative	Negative	Not Voting
PROPOSED REVISION OF STANDARDS			
Standard Methods of Testing Molded Insulating Materials (D 48 - 27)	32	0	10
PROPOSED REVISIONS OF TENTATIVE STANDARDS			
Tentative Methods of Testing Insulating Varnishes (D 115 - 26 T)	27	0	15
Tentative Methods of Testing Electrical Porcelain (D 116 - 27 T)	30	1	11
Tentative Methods of Testing Untreated Insulating Paper (D 202 - 27 T)	24	0	18
Tentative Methods of Testing Laminated Sheet Insulating Materials (D 229 - 26 T)	32	0	10
Tentative Methods of Testing Insulating Materials for Resistance to Impact (D 256 - 26 T)	30	0	12
PROPOSED NEW TENTATIVE STANDARD			
Tentative Methods of Testing Varnished Cloth Tapes	28	1	13
WITHDRAWAL OF TENTATIVE STANDARD			
Tentative Methods of Testing Electrical Insulating Materials for Voltage Effects at Radio Frequencies (D 175 - 25 T)	26	0	14

This report has been submitted to letter ballot of the committee, which consists of 52 members; 40 members returned their ballots, of whom 38 have voted affirmatively, none negatively, and 2 have marked their ballots "not voting."

Respectfully submitted on behalf of the committee,

H. S. VASSAR,
Chairman.

T. S. TAYLOR,
Secretary.

EDITORIAL NOTE

The proposed revision of the Standard Methods of Testing Molded Insulating Materials was accepted for publication as tentative and appears on page 1130.

The proposed revisions of the Tentative Methods of Testing Insulating Varnishes; Testing Electrical Porcelain; Testing Untreated Insulating Paper; Testing Laminated Sheet Insulating Materials; and Testing Insulating Materials for Resistance to Impact, were accepted. The tentative methods as revised appear on pages 975 to 1025, respectively.

The proposed Tentative Methods of Testing Varnished Cloth Tapes were accepted for publication as tentative and appear on page 1026.

The withdrawal of the Tentative Methods of Testing Electrical Insulating Materials for Voltage Effects at Radio Frequencies was approved.

REPORT OF COMMITTEE D-11

ON

RUBBER PRODUCTS

Committee D-11 on Rubber Products has held two meetings during the past year, the first at Buffalo, N. Y., on December 1 and 2, 1927, and the second at Akron, Ohio, March 15 and 16, 1928.

The committee is submitting as tentative new methods of chemical analysis of rubber products to supersede the present standard methods; is recommending a revision of the present Tentative Specifications for Insulated Wire and Cable: 30-per-cent Hevea Rubber (D 27 - 21 T); and is recommending the withdrawal of the present standard specifications for fire hose for private department and public department use, to be superseded by specifications prepared by the Sectional Committee on Specifications for Rubber-Lined Fire Hose. It is also recommending the withdrawal of the Standard Specifications for Rubber Belting for Power Transmission (D 53 - 24) and the revision of the Tentative Specifications for Rubber Insulating Tape (D 119 - 27 T) and of the Standard Specifications for Adhesive Tape for General Use for Electrical Purposes (D 69 - 24). The activities of the committee, together with the detailed recommendations concerning actions on standards, are presented below in connection with the reports on the activities of the sub-committees responsible for them.

Sub-Committee I on Mechanical Rubber Hose (N. G. Bruce, acting chairman).—Sub-Committee I is recommending that the hydrostatic pressures on all hose be revised to conform to the revisions made by the American Railway Association, which became effective March 1, 1928. The changes in the Society's specifications required by these revisions are being tabulated and will be considered at the next meeting of Committee D-11.

Sub-Committee II on Belting (E. H. Grafton, chairman).—The present Standard Specifications for Rubber Belting for Power Transmission (D 53 - 24)[1] were originally developed to cover belting of a definite type for railway car axle generator service. Due to the increasing public demands for rubber belting for power transmission and for conveyor purposes the belt manufacturers have realized for several years that the present specifications were such that they could not be considered as a general standard. In fact, at the present time the specifications are not being used as complete specifications for any type of axelite belting.

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 827.

The consumers represented on Committee D-11 had little or no data to substantiate the statements of the manufacturers. Three years ago, the American Petroleum Institute, in preparing specifications for transmission rubber belting, attempted to use the A.S.T.M. Specifications D 53 – 24, but found them to be so incomplete both as to requirements and methods of testing that the committee responsible for the development of these specifications, D. L. Trax, chairman, under the A.P.I., found it necessary to develop new specifications. Upon invitation from Committee D-11, the A.P.I. outlined its reasons why Specifications D 53 – 24 had proved to be unsatisfactory. These were presented before Committee D-11 at its last meeting.

Committee D-11 now recommends that the Standard Specifications for Rubber Belting for Power Transmission (D 53 – 24) be withdrawn. Sub-Committee II has been instructed to prepare new methods for testing rubber belting for power transmission and to recommend a classification for various types of transmission belting. Mr. Trax has accepted an invitation to assist this sub-committee in its development work, placing the data developed by the A.P.I. at the service of the committee. It is expected that the methods of testing and the classification referred to above will be submitted a year hence.

Sub-Committee V on Insulated Wire and Cable (C. B. Martin, chairman).—On the recommendation of Sub-Committee V, Committee D-11 is submitting revisions of the Tentative Specifications for Insulated Wire and Cable: 30-per-cent Hevea Rubber (D 27 – 21 T).[1] The entire portion of the specifications covering insulation, comprising Sections 12 to 23, has been revised as appended to this report[2] in the proposed revised form. The revised requirements were developed by the Sectional Committee on Insulated Wires and Cables for Other than Telephone and Telegraph Use, functioning under the procedure of the American Engineering Standards Committee, and the specifications have been approved as Tentative American Standard by the A.E.S.C. The committee recommends that the present Sections 12 to 23 be replaced by the corresponding sections as appended to this report,[2] the specifications being continued as tentative.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 21, p. 746 (1921); also 1927 Book of A.S.T.M. Tentative Standards, p. 654.

[2] The new requirements have been incorporated in the Tentative Specifications for Insulated Wire and Cable, see p. 1033.—Ed.

In revising the requirements covering insulation, the requirements covering the high voltage test and the insulation resistance test now appearing in the Appendix to the specifications have been incorporated in the revised specifications and the corresponding sections (Sections 2 to 6) should accordingly be omitted from the Appendix to the specifications.

TABLE I.—STRANDING OF FLEXIBLE CABLES.

(AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS STANDARD NO. 30)

Cross Section of Cable		Diameter of Cable, mils	Number of Wires	Size of Each Wire		Construction[c]
Nearest[a] A. w. g. Number	Circular mils[b]			A. w. g.	Diameter, mils	
	2 039 000	1885	703	15.5	53.9	37 by 19
	1 816 000	1779	703	16.0	50.8	37 by 19
	1 617 000	1679	703	16.5	48.0	37 by 19
	1 440 000	1584	703	17.0	45.3	37 by 19
	1 284 000	1496	703	17.5	42.7	37 by 19
	1 103 000	1372	427	16.0	50.8	61 by 7
	874 600	1222	427	17.0	45.3	61 by 7
	693 600	1088	427	18.0	40.3	61 by 7
	550 000	969	427	19.0	35.9	61 by 7
	436 200	863	427	20.0	32.0	61 by 7
	345 900	768	427	21.0	28.5	61 by 7
	274 300	684	427	22.0	25.3	61 by 7
	264 600	671	259	20.0	32.0	37 by 7
0000	209 800	598	259	21.0	28.5	37 by 7
000	171 300	538	133	19.0	35.9	19 by 7
00	135 900	479	133	20.0	32.0	19 by 7
0	107 700	427	133	21.0	28.5	19 by 7
1	82 780	332	91	20.5	30.2	Concentric
2	65 650	295	91	21.5	26.9	Concentric
3	52 060	263	91	22.5	23.9	Concentric
4	39 190	228	61	22.0	25.3	Concentric
5	31 080	203	61	23.0	22.6	Concentric
6	24 650	181	61	24.0	20.1	Concentric
8	17 410	152	61	25.5	16.9	Concentric
10	10 560	118	37	25.5	16.9	Concentric
12	6 640	94	37	27.5	13.4	Concentric
14	4 176	74	37	29.5	10.6	Concentric
Smaller than No. 14	....	....	[d]	30.0	....	Bunched

[a] The A. w. g. cross-sectional areas except for 61-strand cable are approximated within 2 per cent. In the case of 61-strand cables the approximation is 6 per cent.

[b] Circular mils are based on theoretical diameters of A. w. g. sizes, which vary above or below values given in the table by less than 0.1 mil.

[c] A construction of "61 by 7" in the rating of a rope-lay cable signifies 61 strands of 7 wires each.

[d] As required to equal the size specified.

In addition to these revisions the committee is recommending editorial revision of Table I referred to in Section 5, comprising the insertion of circular mil designations for the various sizes of cables in place of the present designations in terms of circular inches, and the revision of the present Table II to conform to the accompanying Table I. Editorial revisions are also being made in Table III and in the table appearing in Section 10 by the incorporation of equivalent A.w.g. numbers for the present sizes specified.

Sub-Committee IX on Insulating Tape (J. M. Bierer, chairman).—The present Tentative Specifications for Rubber Insulating Tape

(D 119 - 27 T)[1] and the present tentative revisions of the Standard Specifications for Adhesive Tape for General Use for Electrical Purposes (D 69 - 24)[2] give a description of a method of test for adhesion. An illustration of the tape tester is shown in the accompanying Fig. 1 and it is recommended by the committee that this figure be incorporated in the two specifications in question, in connection with the description of the test for adhesion.

Sub-Committee XI on Chemical Analysis of Rubber Products (S. Collier, chairman).—The present analytical methods appearing in the Standard Methods of Testing Rubber Products (D 15 - 24)[3] do not agree with the methods approved by the American Chemical Society. These latter methods are the ones generally used and Committee D-11 recommends that the methods of analysis be revised to agree with those of the American Chemical Society and submits for publication as tentative the methods of chemical analysis appended hereto[4] to supersede, when adopted, the present standard methods, comprising Sections 1 to 47 of Methods D 15.

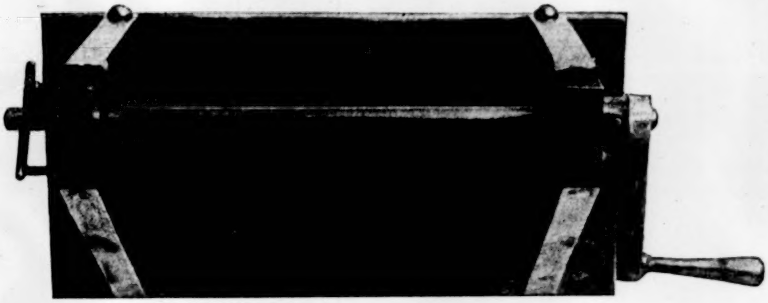

FIG. 1.—Illustration of Tape Tester.

Sub-Committee XIV on Abrasion Tests for Rubber Products (H. A. Depew, chairman).—The sub-committee has been making a series of laboratory tests and service tests and is now attempting the correlation of these tests. The laboratory tests have been completed and results from a considerable number of the service tests are available. Additional tests will be available at the fall meeting of the committee.

The sub-committee plans to submit tentative methods for conducting several types of abrasion tests a year hence.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 1028 (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 674.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 1097 (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 771.

[3] 1927 Book of A.S.T.M. Standards, Part II, p. 847.

[4] See p. 1072.—ED.

Sub-Committee XV on Life Tests for Rubber Products (Stanley Krall, chairman).—Sub-Committee XV is starting a series of aging tests. Two cures of each of three compounds have been submitted to each member of the committee for the purpose of making tension tests after treatments as follows: As received, after aging in the Geer oven, after aging in the Bierer-Davis bomb, after storage in the dark under controlled conditions, and after storage exposed to the light, the conditions for the two latter tests being noted and reported.

Sub-Committee XVI on Flexing Tests for Rubber Products (W. L. Sturtevant, chairman).—This sub-committee is carrying on additional test work attempting to correlate the flexing machine test on rubber belting with the dynamometer machine tests.

The committee believes that the flexing machine it has developed is very valuable but is not ready to be adopted as a standard method of testing belting.

Sub-Committee XVII on Rubber Products for Absorbing Vibration (L. C. Conradi, chairman).—This sub-committee is cooperating with the Society of Automotive Engineers in the development of specifications and methods of testing rubber products used in automobile construction, such as the rubber blocks that absorb engine vibration. The sub-committee felt that first of all a test method was needed for determining the hardness of rubber stocks, since such a test could be used as a control test on the uniformity of successive shipments of rubber products.

The sub-committee found that none of the existing hardness testing machines afforded the desired accuracy and simplicity, so the committee is now cooperating with the instrument makers toward the development of a satisfactory hardness tester. Present indications are favorable to the successful development of such a device.

As mentioned earlier in this report, the present standard specifications for fire hose are recommended for withdrawal, to be superseded by specifications for fire hose covering both private and public fire department use, prepared by the Sectional Committee on Specifications for Rubber-Lined Fire Hose, functioning under the rules of procedure of the American Engineering Standards Committee. The specifications recommended for withdrawal are the Standard Specifications for Cotton Rubber-Lined Fire Hose for Private Fire Department Use (D 14 – 23)[1] and the Standard Specifications for Cotton Rubber-Lined Fire Hose for Public Fire Department Use (D 26 – 23).[2]

The committee has elected the following officers to serve for the ensuing term of two years: L. C. Conradi, chairman; C. R. Boggs, vice-chairman; and Arthur W. Carpenter, secretary.

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 804.

[2] *Ibid.*, p. 810.

The recommendations appearing in this report have been submitted to letter ballot with the following results:

Items	Affirmative	Negative	Not Voting
1. Submission as tentative of Methods of Chemical Analysis of Rubber Products	25	0	1
2. Submission as tentative of Specifications for Cotton Rubber-Lined Fire Hose for Public and Private Fire Department Use	21	2	2
3. Proposed revision of Tentative Specifications for Insulated Wire and Cable: 30-per-cent Hevea Rubber (D 27 - 21 T)	19	1	5
4. Proposed revision of Tentative Specifications for Rubber Insulating Tape (D 119 - 27 T)	23	0	3
5. Proposed revision of Standard Specifications for Adhesive Tape for General Use for Electrical Purposes (D 69 - 24)	23	0	3
6. Withdrawal of Standard Specifications for Cotton Rubber-Lined Fire Hose for Private Fire Department Use (D 14 - 23)	21	1	3
7. Withdrawal of Standard Specifications for Cotton Rubber-Lined Fire Hose for Public Fire Department Use (D 26 - 23)	21	1	3
8. Withdrawal of Standard Specifications for Rubber Belting for Power Transmission (D 53 - 24)	20	1	4

This report has been submitted to letter ballot of the committee, which consists of 62 members; 28 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

F. G. BREYER,
Chairman.

E. H. GRAFTON,
Secretary.

EDITORIAL NOTE

The proposed Methods of Chemical Analysis of Rubber Products were accepted for publication as tentative, to supersede, when adopted, the chemical tests appearing in the Standard Methods of Testing Rubber Products (D 15 - 24). The tentative methods appear on page 1072.

The proposed Specifications for Cotton Rubber-Lined Fire Hose for Public and Private Fire Department Use were accepted for publication as tentative, to supersede the Standard Specifications for Cotton Rubber-Lined Fire Hose for Private Fire Department Use, and for Cotton Rubber-Lined Fire Hose for Public Fire Department Use, and appear on page 1050. The standard specifications were accordingly withdrawn.

The proposed revisions of the Tentative Specifications for Insulated Wire and Cable: 30-per-cent Hevea Rubber; and for Rubber Insulating Tape were accepted. The tentative specifications in their revised form appear on pages 1033 and 1068, respectively.

The proposed revision of the Standard Specifications for Adhesive Tape for General Use for Electrical Purposes was approved at the annual meeting by a nine-tenths vote and was subsequently adopted by letter ballot of the Society on September 1, 1928. The specifications in their revised form appear in the 1928 Supplement to Book of A.S.T.M. Standards.

The withdrawal of the Standard Specifications for Rubber Belting for Power Transmission was approved.

REPORT OF SECTIONAL COMMITTEE

ON

SPECIFICATIONS FOR RUBBER-LINED FIRE HOSE

The Sectional Committee on Specifications for Rubber-Lined Fire Hose was organized November 5, 1926, in accordance with the procedure of the American Engineering Standards Committee, under the joint sponsorship of the A.E.S.C. Fire Protection Group and the American Society for Testing Materials. The personnel of the committee as approved by the American Engineering Standards Committee is as follows:

Organization Represented	Name of Representative
American Marine Standards Committee	A. R. Small, Underwriters' Laboratory, New York City.
American Society for Testing Materials	H. L. Miner, Manager, Fire Protective and Ins. Div., duPont de Nemours & Co., Wilmington, Del. W. L. Sturtevant, Manhattan Rubber Co., Passaic, N. J.
Associated Factory Mutual Fire Insurance Co.	G. W. Angell, Boston, Mass. C. W. Mowry, Boston, Mass.
Federal Specifications Board	P. L. Wormeley, Bureau of Standards, Washington, D. C.
International City Managers Association	William A. Holt, City Manager, New London, Conn.
National Fire Protection Association	Ross B. Davis, Chief Engr., Fire Dept., Philadelphia, Pa.
New York City, Purchasing Dept.	Frederick Kenney, Central Testing Laboratory, 125 Worth St., New York City.
Railway Fire Protection Association	J. R. Peters, Asst. to Supt. Ins. Dept., Pennsylvania R. R., Philadelphia, Pa.
Rubber Association of America	W. H. Cobb, U. S. Rubber Co., 1790 Broadway, New York City. E. H. Grafton,[1] C. Kenyon Co., First Avenue and 57th Street, Brooklyn, N. Y. L. J. Howell, Chief Chemist, Hamilton Rubber Co., Trenton, N. J.
Underwriters' Laboratories	C. J. Krieger, New York City. A. H. Nuckolls, Chicago, Ill.

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[1] Formerly of the Murray Rubber Co., Trenton, N. J.

The problem placed before the committee was the development of standards for construction and performance under test of rubber-lined fire hose for use by private and public fire departments, a problem primarily of unifying the existing specifications covering this product. At the time this work was started there were in effect specifications published by the Underwriters' Laboratories, the Factory Mutual Laboratories, the Federal Government, the American Society for Testing Materials, the American Railway Association and several others, some of which had been in effect for ten or twelve years. While these specifications differed from one another, the differences were in the main so slight that it was apparent that unification could be accomplished without changing the intent of any of the specifications to any important degree. The most important differences were with respect to chemical requirements for the rubber lining and requirements for diameter of hose. There were also minor variations between the several specifications, such as requirements for elongation, twist, etc., which were so slight as to be practically negligible.

Active work by the committee began on the day of its organization, and on November 18, 1926, the first draft of a specification was mailed to the members of the committee for study, several items being in doubt and incomplete. This draft was considered at the committee's second meeting held December 10, 1926, and the unsettled matters were provisionally completed at that time. This resulted in a second draft of the specification, which was offered to the committee for letter ballot on January 10, 1927. This letter ballot resulted in several negative votes and after unsuccessful attempts to obtain agreement by correspondence, a third meeting of the committee was held on March 21, 1927. Shortly thereafter a second letter ballot was sent out. This ballot brought up two items of such a controversial nature that almost a year of additional correspondence and ballots ensued before a final agreement was reached early in 1928. This agreement was in the nature of a compromise on a standard for $2\frac{1}{2}$-in. diameter fire hose, the minimum inside diameter being fixed at $2\frac{9}{16}$ in. with the understanding that the hose will continue to be known and identified as $2\frac{1}{2}$-in. hose. The requirements of the rubber compound were adjusted so as to fully meet the "rubber by volume" requirements of the Federal Specifications, adhering in general to the methods of test in effect in the specifications of the Underwriters' Laboratories and the A.S.T.M. The net result is a slightly more severe chemical specification than existed when the committee started its work. A final draft of the specifications, now appended to this report,[1] was prepared and sent to a letter ballot of the committee, with the recommendation that the specifications if approved by the sponsor bodies be submitted to the American Engineering Standards Committee for approval as Tentative American Standard. The result of this ballot was 13 affirmative, none negative, two not voting. Mr. Frederick Kenney, representing the Purchasing Department of the City of New York, has not voted; and the chairman did not vote officially but has informally approved the specifications.

The committee wishes to call particular attention to the inclusion in these specifications of the so-called Geer life test. This test has been included as being representative of current practice but the committee feels that research now being conducted by the American Society for Testing Materials through its Committee D-11 on Rubber Products will eventually produce a superior test, which should be adopted when developed.

Respectfully submitted on behalf of the sectional committee,

P. L. WORMELEY,
Chairman.

C. J. KRIEGER,
Secretary.

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[1] See p. 1050.—ED.

EDITORIAL NOTE

The proposed Specifications for Cotton Rubber-Lined Fire Hose for Public and Private Fire Department Use were accepted for publication as tentative and appear on page 1050.

REPORT OF COMMITTEE D-13
ON
TEXTILE MATERIALS

Committee D-13 on Textile Materials held two meetings during the year. The fall meeting was held at Atlanta, Ga., on October 19, 20 and 21, 1927. The spring meeting was held at Providence, R. I., on March 7, 8 and 9, 1928. Both meetings brought out new discussion and suggested new work and were, on the whole, quite satisfactory.

One new sub-committee has been authorized during the year:

Sub-Committee XXII on Finishes and Finishing Materials.

This sub-committee is an outgrowth of the application of weight and quality tests wherein finishing affects the result. The sub-committee is not yet organized but should be in action before the next fall meeting.

Committee D-13 submits two new tentative specifications and a number of tentative definitions of terms as appended hereto:[1]

1. Tentative Specifications for Tolerances and Test Methods for Asbestos Yarns.
2. Tentative Specifications and Tolerances for 23/5/3 Carded American Tire Cord.
3. Tentative Definitions of Terms Relating to Textile Materials.

The first of the new tentative specifications is the first formal result of the work of sub-Committee XVI on Asbestos Textiles. The original request for standards on asbestos textiles was received from one of the large users of insulating materials for electrical purposes. On canvassing the field it was thought best to first prepare tentative specifications for asbestos yarn in general and to take up later specific insulating materials and other asbestos textile materials.

The second of these new tentative standards is the first formal result of the new departure of Committee D-13 to write specifications for textile materials for specific uses. These specifications were prepared in response to a number of requests received from producers and non-producers for definite specifications covering carded American tire cord.

The third is a series of definitions relating to yarns, cords and fabrics to be incorporated, if finally advanced to standard, in the Standard Definitions of Terms Relating to Textile Materials (D 123 – 27).[2]

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[1] See pp. 1096, 1103, and 1105, respectively.—Ed.

[2] 1927 Book of A.S.T.M. Standards, Part II, p 905.

The committee recommends that the definitions for "regain (moisture regain)," "loop-knot" and "gage" which have been published as tentative for the past year under the title Definitions of Terms Relating to Textile Materials (D 123 - 27 T) be continued as tentative without change, pending further study of suggestions made by Committee E-8 on Nomenclature and Definitions.

Committee D-13 recommends the following revisions of Tentative Specifications for Tolerances and Test Methods for Knit Goods (D 231 - 25 T),[1] the specifications to be continued as tentative:

Section 8.—Omit the material under Section 8, constituting a description of the method of determining the percentage of cotton and wool and insert a new Section 8 to read as follows:

> The amount of cotton and wool present shall be determined in accordance with the method prescribed for cotton and wool mixtures in the Tentative Methods for Identification of Textile Fibers and Their Quantitative Determination in Mixed Goods (Serial Designation: D 276 - 27 T) of the American Society for Testing Materials.

Section 9. (a).—Change to read as follows by the addition of the italicized words:

> 9. (*a*). The width of the roll or piece (either split or tubular) shall be determined at five different places uniformly distributed along the full length of the roll or piece. *No measurement within 8 yards of either end of the roll or piece shall be considered.* The goods shall be drawn across a table without tension when the width is measured.

Section 10.—Change from its present form: namely,

> 10. (*a*) Five samples which have been died out in staggered fashion across the roll or piece shall be weighed collectively. The die shall be square and 2 in. on a side. The material shall not be under tension as it is sampled.
>
> (*b*) The samples shall be weighed under prevailing atmospheric conditions except in the settlement of disputes. In such cases, tests shall be made upon samples which have normal moisture content, obtained by exposure for at least 4 hours to an atmosphere of 65 per cent relative humidity at a temperature of 70° F. (21° C.); or upon agreement, the samples shall be weighed in the dry condition as described in section 2 of the Standard Methods of Testing Cotton Fabrics (Serial Designation: D 39) of the American Society for Testing Materials.
>
> (*c*) The weight shall be reported as weight per square yard as calculated from the weight found.

to read as follows:

> 10. (*a*) The average square yard weight shall be determined from the weight of the roll or piece and the square yard area calculated from the length

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 25, Part I, p. 842 (1925); also 1927 Book of A.S.T.M. Tentative Standards, p. 685.

and width. The width shall be determined as described in Section 9 (*a*). For the determination of length and width a rewinding machine shall be used. The machine shall be equipped with an accurate length measuring device and the driving rolls shall travel at the same surface speed. The goods shall be drawn over the table without tension.

(*b*) *Alternate Method.*—Five samples which have been died out in staggered fashion across the roll or piece shall be weighed collectively. The die shall be square and 2 in. square on a side. The material shall not be under tension as it is sampled.

(*c*) The weight shall be determined under prevailing atmospheric conditions except in the settlement of disputes. In such cases the moisture regain shall be determined as in Section 6 (*a*) on four 2 by 2-in. samples two died from each end of the roll or piece and the average square yard weight corrected to standard conditions.

(*d*) The weight shall be reported as weight per square yard as calculated from the weight found.

Change the sub-title "Tensile Strength" to read "Strength (Bursting)."

Section 13.—Change Paragraph (*a*) to read as follows by the addition of the italicized words and the omission of the word in brackets:

> 13. (*a*). The [tensile] strength shall be determined on an approved type of inclination balance breaking machine. *The sample shall be securely held by a ring mechanism not less than $1\frac{3}{4}$ in. in internal diameter and be drawn down against a 1-in. polished steel ball until a burst is produced.* The maximum capacity of the machine shall be such that the position of the pendulum shall not be greater than 45 deg. from the vertical when the break occurs. The minimum capacity shall not be less than 20 per cent of the above maximum capacity.

Omit Paragraph (*c*) reading as follows, relettering the subsequent paragraphs accordingly:

> (*c*). The 1 by 1 by 1-in. grab method shall be used as described in Section 19 (*d*) of the Standard Methods of Testing Cotton Fabrics (Serial Designation: D 39), with the single exception that the distance between jaws shall be changed from 3 in. to 1 in.

Reletter Paragraph (*d*) to Paragraph (*c*) and change to read as follows by the addition of the italicized words and the omission of the words in brackets:

> (*c*). At least [20] *10* test pieces [4 in. in width by 6 in. in length] shall be cut, [ten in the direction of the wales and ten in the direction of the courses] *the smallest dimension of which shall be at least $\frac{1}{2}$ in. greater than the outside diameter of the ring mechanism referred to in Section 13* (*a*).

Reletter Paragraph (*e*) to Paragraph (*d*) and change to read as follows by the omission of the words in brackets:

> (*d*). The [tensile] strength [in each direction] shall be the average of ten tests.

Committee D-13 recommends that the following six tentative standards be continued without revision:

Tentative Methods of Testing Cotton Fibers (D 152 – 22 T);

Tentative Methods of Testing Grease Wool and Allied Fibers for Scoured Content (D 232 – 25 T);

Tentative Specifications for Tolerances and Test Methods for Rayon (D 258 – 27 T);

Tentative Specifications for Tolerances and Test Methods for Certain Light and Medium Cotton Fabrics (D 274 – 27 T);

Tentative Specifications and Tests for Cuban (Jute) Raw Sugar Bags (D 275 - 27 T);

Tentative Methods for Identification of Textile Fibers and Their Quantitative Determination in Mixed Goods (D 276 – 27 T).

The first has been tentative since 1922 but some work in progress in the new Sub-Committee on Raw Cotton makes it inadvisable to recommend any changes in its status at the present time.

The second and third are being investigated in respect to a moot point of moisture regain. It is recommended by the committee that a note be appended to the third as follows:

NOTE.—In commercial transactions $11\frac{1}{2}$ per cent regain is commonly used.

The fourth, fifth and sixth are continued without revision and will probably be recommended for advancement to standard during the coming year.

The recommendations contained in this report have been submitted to letter ballot of the committee with the following results:

Items	Affirmative	Negative	Not Voting
I. NEW TENTATIVE STANDARDS			
1. Tentative Specifications for Tolerances and Test Methods for Asbestos Yarns	21	0	39
2. Tentative Specifications and Tolerances for 23/5/3 Carded American Tire Cord	29	4	27
3. Tentative Definitions of Terms Relating to Textile Materials	46	2	12
II. REVISIONS OF TENTATIVE STANDARD			
4. Tentative Specifications for Tolerances and Test Methods for Knit Goods (D 231 – 25 T)	21	1	38

The following officers were elected for the two-year period June, 1928, to June, 1930

Chairman, W. H. Whitcomb.
First Vice-Chairman, K. B. Cook.
Second Vice-Chairman, D. C. Scott.
Secretary, D. G. Wolfe.

This report has been submitted to letter ballot of the committee, which consists of 165 members; 60 members returned their ballots, of whom 52 have voted affirmatively, none negatively, and 8 have marked their ballots "not voting."

Respectfully submitted on behalf of the committee,

W. F. EDWARDS,
Chairman.

K. B. COOK,
Secretary.

EDITORIAL NOTE

The proposed Specifications for Tolerances and Test Methods for Asbestos Yarns; Specifications and Tolerances for 23/5/3 Carded American Tire Cord; and Definitions of Terms Relating to Textile Materials were accepted for publication as tentative and appear on pages 1096, 1103 and 1105, respectively.

The proposed revisions of the Tentative Specifications for Tolerances and Test Methods for Knit Goods were accepted. The tentative specifications in their revised form appear on page 1099.

REPORT OF COMMITTEE D-15
ON
THERMOMETERS

During the past year, Committee D-15 has given further attention to requests for the standardization of specifications for thermometers for incorporation in the standard methods of testing of the Society. It was appreciated that the importance of the heating test for raw tung oil, described in the Standard Specifications for Raw Tung Oil (D 12 - 25 T) required a more specifically described thermometer than that appearing in the method as now printed, and Committee D-15 has prepared and recommends the specifications appearing in Appendix I to this report to Committee D-1 on Preservative Coatings for Structural Materials, the committee having jurisdiction over the specifications in question.

Committee D-2 on Petroleum Products and Lubricants has requested specifications for a thermometer to be used in the determination of the specific gravity of petroleum products, and specifications have been prepared appearing as Appendix II to this report which are recommended for this purpose. They have also been incorporated in the Tentative Method of Test for Gravity of Petroleum and Petroleum Products by Means of the Hydrometer (D 287 - 28 T), which is being submitted this year by that committee.[1]

The Engler viscosimeter, the use of which has not been standardized by the Society, is, nevertheless, widely used in the testing of bituminous road materials, and its use is required by reference in the Society's specifications for tar for use cold in road construction (Serial Designations: D 104 - 27 T; D 105 - 27 T; D 106 - 27 T; D 107 - 27 T). Committee D-4 on Road and Paving Materials, having jurisdiction over these specifications, is at present making a comparative study of the Engler viscosimeter and the need was expressed for properly standardized thermometers for the various temperature ranges covered by American practice in road materials testing. Committee D-15 has, therefore, prepared and recommends the appended specifications[2] covering four suitable thermometers.

The chairman of the committee presented a paper before the International Road Congress in September, 1927, reviewing the needs for standardization of thermometers and the results that have been accomplished in that direction in this country.

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[1] See p. 924.—Ed.

[2] See p. 1108.—Ed.

The committee has re-elected the present officers to serve for the ensuing term of two years.

The recommendations embodied in this report have been submitted to letter ballot of the committee, which consists of 13 members; 10 ballots have been returned and 3 members have refrained from voting. The result of the letter ballot is as follows:

Items	Affirmative	Negative	Not Voting
I. PROPOSED STANDARDS			
Thermometer for Heating Test of Raw Tung Oil	9	1	0
Thermometer for Specific Gravity Determination	9	1	0
II. PROPOSED TENTATIVE STANDARDS			
Thermometers for Engler Viscosimeter	9	1	0

This report has been submitted to letter ballot of the committee, which consists of 13 members; 10 members returned their ballots, of whom 9 have voted affirmatively, 1 negatively, and none has marked his ballot "not voting."

Respectfully submitted on behalf of the committee,

W. H. FULWEILER,
Chairman.

C. S. REEVE,
Secretary.

EDITORIAL NOTE

The proposed Specifications for Thermometers for Engler Viscosimeters were accepted for publication as tentative and appear on page 1108.

APPENDIX I

PROPOSED SPECIFICATIONS FOR THERMOMETER FOR HEATING TEST OF RAW TUNG OIL

The thermometer shall conform to the following requirements. These specifications cover a special thermometer graduated in either Centigrade or Fahrenheit degress as specified, the ranges being 210 to 310° C. or 410 to 590° F.

TYPE: Etched stem, glass.

LIQUID: Mercury.

RANGE AND SUBDIVISION: 210 to 310° C. in 2° C. or 410 to 590° F. in 5° F

TOTAL LENGTH: 112 to 116 mm. (4.41 to 4.57 in.).

STEM: Plain point, enamel back, suitable thermometer tubing.
Diameter 6 to 7 mm. (0.236 to 0.275 in.).

BULB: Corning normal or equally suitable thermometer glass.
Length 6.5 to 9.5 mm. (0.256 to 0.374 in.).
Diameter not greater than stem.

DISTANCE TO 210° C. OR 410° F. LINE FROM BOTTOM OF BULB: 25 to 32 mm. (0.98 to 1.26 in.).

DISTANCE TO 310° C. OR 590° F. LINE FROM TOP OF THERMOMETER: 12 to 19 mm. (0.47 to 0.75 in.).

CONTRACTION CHAMBER: Top to be not more than 19 mm. (0.75 in.) above bottom of bulb.

FILLING ABOVE MERCURY: Nitrogen gas.

TOP FINISH: Plain.

GRADUATIONS: All lines, figures and letters clear cut and distinct. The first and each succeeding 10° C. line to be longer than the intermediate lines. Graduations to be numbered at each multiple of 20° C. or at 420° F. and each succeeding 40° F. line.

IMMERSION: Total.

SPECIAL MARKING: "A.S.T.M. Tung," a serial number and the manufacturer's name or trade mark shall be etched on the stem.

SCALE ERROR: The error at any point of the scale when the thermometer is standardized as provided below shall not exceed 2° C. or 4° F.

STANDARDIZATION: The thermometer shall be standardized immersed in the test bath to the top of the mercury column at intervals of approximately 50° C. or 90° F.

CASE: The thermometer shall be supplied in a suitable case on which shall appear the marking: "A.S.T.M. Tung 210 to 310° C." or "A.S.T.M. Tung 410 to 590° F." according to the type of thermometer.

NOTE.—For the purpose of interpreting these specifications, the following definitions apply:

The total length is the over-all length of the finished instrument.

The diameter is that measured with a ring gage.

The length of the bulb is the distance from the bottom of the bulb to the beginning of the enamel backing.

The top of the thermometer is the top of the finished instrument.

APPENDIX II

PROPOSED SPECIFICATIONS FOR THERMOMETER FOR SPECIFIC GRAVITY DETERMINATION

The thermometer shall conform to the following requirements. These specifications cover a total immersion thermometer graduated in either Centigrade or Fahrenheit degrees as specified, the ranges being −20 to +102° C. or −5 to +215° F., respectively. The purpose of these specifications is to provide a thermometer suitable for use in the determination of specific gravity of petroleum products.

TYPE: Etched stem, glass.

LIQUID: Mercury.

RANGE AND SUBDIVISIONS: −20 to +102° C. in 0.2° C. or −5 to +215° F. in 0.5° F.

TOTAL LENGTH: 403 to 409 mm. (15.87 to 16.10 in.).

STEM: Plain front, enamel back, suitable thermometer tubing.
Diameter 7 to 8 mm. (0.276 to 0.314 in.).

BULB: Corning normal or equally suitable thermometer glass, heavy wall.
Length 14 to 19 mm. (0.55 to 0.75 in.).
Diameter 6 to 7 mm. (0.236 to 0.275 in.).

DISTANCE TO −20° C. OR −5° F. LINE FROM BOTTOM OF BULB: 32 to 51 mm. (1.26 to 2.00 in.).

DISTANCE TO +102° C. OR +215° F. LINE FROM TOP OF THERMOMETER: 25 to 45 mm. (0.98 to 1.77 in.).

FILLING ABOVE MERCURY: Nitrogen gas.

TOP FINISH: Glass ring.

GRADUATIONS: All lines, figures and letters clear cut and distinct. Each whole degree Centigrade or Fahrenheit line to be longer than the remaining lines. Graduations to be numbered at each multiple of 2° C. or 5° F.

IMMERSION: Total.

SPECIAL MARKING: "A.S.T.M. Sp. gr.," a serial number and the manufacturer's name or trade mark shall be etched on the stem.

SCALE ERROR: The error at any point of the scale when the thermometer is standardized as provided below shall not exceed 0.2° C. or 0.5° F.

STANDARDIZATION: The thermometer shall be standardized immersed in the testing bath to the top of the mercury column, at the ice point and at temperature intervals of from 15 to 20° C. or 30 to 40° F.

CASE: The thermometer shall be supplied in a suitable case on which shall appear the marking: "A.S.T.M. Sp. gr. −20 to +102° C." or "A.S.T.M. Sp. gr. −5 to +215° F." according to the type of thermometer.

NOTE.—For the purpose of interpreting these specifications the following definitions apply:

The total length is the over-all length of the finished instrument.

The diameter is that measured with a ring gage.

The length of the bulb is the distance from the bottom of the bulb to the beginning of the enamel backing.

The top of the thermometer is the top of the finished instrument.

REPORT OF COMMITTEE D-16
ON
SLATE

The activities of the committee during the past year have consisted mainly in a continuation of investigational work by various sub-committees, the holding of three meetings including a meeting in conjunction with the annual meeting of the Society, the inauguration of a mineral industries conference and the presentation of papers and the discussions thereon at meetings and conferences. No changes are recommended at this time in existing tentative standards or in their status.

At a mid-year meeting held in New York City in connection with the National Slate Association's Convention, plans were laid for further research in connection with the development of test procedures. The progress of this work is described in the report of Sub-Committee I on Methods of Testing.

The spring meeting of Committee D-16 was held in connection with the Lehigh Valley Mineral Industries Conference which began on April 25 at Easton, Pa., and continued for three days. For several months in advance of these dates, three members of the committee acted as officers of this Conference and received the cordial cooperative support of Lafayette College, Lehigh University and the following organizations in arranging the details of what proved to be a most interesting and informative occasion: Engineers Club of the Lehigh Valley; Lehigh Valley Section, American Institute of Mining and Metallurgical Engineers; Lehigh Valley Section, American Society Mechanical Engineers; Structural Service Department, American Institute of Architects; U. S. Bureau of Mines, Non-Metallic Minerals Station; Pennsylvania State Chamber of Commerce; Structural Service Bureau; Easton Board of Trade; Northampton County Bankers Association; Rotary and Kiwanis Clubs of Easton and Bethlehem.

Among the papers presented and discussed at the meeting and session devoted to slate were the following:

"Physical Testing of Slate in Mining Engineering Laboratory of Lafayette College," by Assistant Professor C. W. Macdougall, Lafayette College.

"The Mineral Resources of Eastern Pennsylvania," by Dr. George N. Ashley, State Geologist of Pennsylvania.

"The Geology of Slate," by Professor Charles H. Behre, Jr., University of Cincinnati.

"The Wire Saw in Slate Quarrying," by Dr. Oliver Bowles, Superintendent, U. S. Bureau of Mines Experiment Station, New Brunswick, N. J.

"The Architectural Uses of Slate," by Donald M. Kirkpatrick, Architect, Philadelphia, Pa.

The program included technical sessions and meetings with addresses, moving pictures and entertainment features, in addition to inspection trips to slate quarries and mills, and cement and steel plants.

Sub-Committee I on Methods of Testing:

At a meeting of Sub-Committee I in New York City on January 17, 1928, it was decided that further comparative tests on slate were desirable. Since the first attempt to obtain comparative tests between different laboratories was not entirely satisfactory on account of the fact that the various samples were not uniform it was decided to try a series of repeat tests on the same specimens. Absorption tests and elasticity tests can be repeated on the same specimens but strength tests cannot. Although it was not definitely known whether the necessary oven drying or the repeated stressing of slate would cause appreciable injury and hence affect the results, it was considered worth the attempt to obtain comparative results in this manner.

Four samples of slate from different localities were cut into specimens as follows: Sample No. 39, Buckingham, Va., slate; sample No. 40, "Hard Vein Black Roofing Slate" from Chapman, Pa.; sample No. 48, Fairmount, Ga., slate; and sample No. 126 "Arabian Red Slate" from Granville, N. Y. Three flexure test specimens and three absorption specimens were prepared at the U. S. Bureau of Standards from each sample in accordance with the requirements of the Tentative Method of Test for Water Absorption of Slate (D 221 - 27 T)[1] and the Tentative Methods of Flexure Testing of Slate (D 222 - 27 T).[1] All three absorption specimens of each were repeatedly tested by four operators. One of the flexure specimens of each sample was tested to the breaking point to determine the safe loads that could be placed on the others. The other two flexure specimens of each group were then tested for elasticity by the same four operators in succession. The results obtained are given in Tables I and II, the tests being made in the following order: (1) Operator A, results of tests by Mr. Kessler at the Bureau of Standards; (2) Operator B, results of tests by Mr. Sligh at the Bureau

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, pp. 972, 974 (1927); also 1927 Book of A.S.T.M. Tentative Standards, pp. 560, 562.

TABLE I.—RESULTS OF ABSORPTION TESTS OF SLATE.

Specimen	Absorption, per cent			
	Operator A	Operator B	Operator C	Operator D
No. 39-1	0.01	0.02	0.08	0.11
2	0.02	0.03	0.17	0.12
3	0.00	0.02	0.00	0.02
Average	0.01	0.02	0.08	0.08
No. 40-1	0.14	0.15	0.23	0.21
2	0.16	0.17	0.20	0.09
3	0.15	0.15	0.12	0.15
Average	0.15	0.16	0.18	0.15
No. 48-1	0.10	0.12	0.11	0.08
2	0.09	0.10	0.39	0.07
3	0.10	0.11	0.29	0.24
Average	0.10	0.11	0.26	0.13
No. 126-1	0.07	0.10	0.49	0.08
2	0.11	0.10	0.39	0.08
3	0.15	0.14	0.25	0.23
Average	0.11	0.11	0.38	0.13

TABLE II.—RESULTS OF MODULUS OF ELASTICITY MEASUREMENTS ON SLATE.

Specimen	Modulus of Rupture, lb. per sq. in.	Modulus of Elasticity, lb. per sq. in.					
		Operator A	Operator B	Operator C		Operator D	Grand Average, lb. per sq. in.
				Series 1	Series 2		
No. 39-1	9 470	15 360 000	....	....	....	....	
2	....	15 990 000	16 480 000	17 900 000	18 200 000	16 800 000	
3	....	15 320 000	16 350 000	17 700 000	18 200 000	17 150 000	
Average	....	15 560 000	16 410 000	17 800 000	18 200 000	16 980 000	16 990 000
Variation from general average, per cent	....	−8.4	−3.4	+4.8	+7.1	−0.6	
No. 40-1	13 120	13 890 000	....	....	....	....	
2	....	14 390 000	14 390 000	16 950 000	17 750 000	15 150 000	
3	....	15 980 000	16 200 000	20 200 000	17 300 000	16 100 000	
Average	....	14 750 000	15 300 000	18 580 000	17 520 000	15 620 000	16 390 000
Variation from general average, per cent	....	−10.0	−6.7	+13.4	+6.9	−4.7	
No. 48-1	11 600	17 460 000	....	....	....	....	
2	....	18 310 000	18 620 000	18 800 000	17 900 000	19 580 000	
3	....	17 650 000	18 190 000	19 250 000	19 250 000	17 700 000	
Average	....	17 800 000	18 400 000	19 020 000	18 580 000	18 640 000	18 490 000
Variation from general average, per cent	....	−3.7	−0.5	+2.9	+0.5	+0.8	
No. 126-1	6 870	13 700 000	....	....	....	....	
2	....	14 650 000	14 020 000	14 650 000	14 650 000	14 490 000	
3	....	13 180 000	13 740 000	16 450 000	16 000 000	15 030 000	
Average	....	13 840 000	13 880 000	15 550 000	15 320 000	14 760 000	14 670 000
Variation from general average, per cent	....	−5.7	−5.4	+6.0	+4.4	+0.6	
Average of variations from grand average, per cent	....	−7.0	−4.0	+6.8	+4.7	−1.0	

of Standards; (3) Operator C, results of tests by Professor Lawson and associates at Rensselaer Polytechnic Institute; (4) Operator D, results of tests by Professor Macdougall at Lafayette College. In the table of elasticity values, Table II, two columns appear under Operator C, representing two series of tests by Professor Lawson on the same specimens. The first series was made with the usual type of knife edges and the second with knife edges not provided with the adjusting rocker.

The absorption results are disappointing since in three cases out of four they indicate a total lack of agreement. While there is considerable evidence that the repeated heating of the specimens causes an increase in absorption, this effect is not progressive, since the third repetition indicated in three cases out of four the highest results while the fourth agrees reasonably well with the first in all cases except one. Evidently this test requires further study before a reliable standard can be recommended.

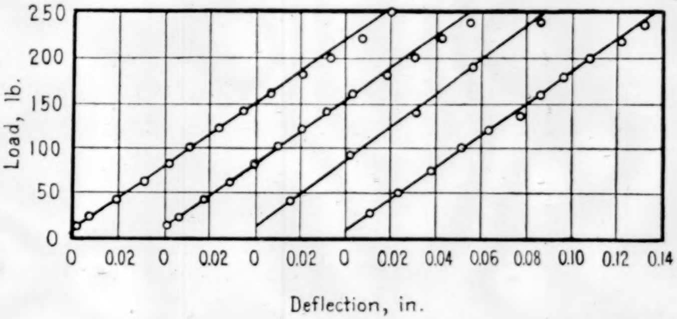

FIG. 1.—Stress-Strain Curves Obtained by Four Operators on Same Specimen.

The elasticity results are considered reasonably good since the greatest individual average differs from the grand average by only 13.4 per cent and in only one other case is it as great as 10 per cent. There is evidence here that the repeated stressing of the material increases the modulus of elasticity. This is rather to be expected and is in accordance with the available data on other materials in this respect.

In Fig. 1 are shown the stress-strain curves obtained by the four operators for specimen No. 39–2, which are typical of the agreement obtained in all the tests. When it is recalled that it is the slope of this line that determines the value of the modulus of elasticity, one may see that these determinations are in very good agreement. The drawing of the average line through the points obtained may account for some of the variations since two men might draw a line for the same points with a slightly different slope. Inaccuracies of the deflection gage may also be an important consideration.

Since these results are in reasonably good agreement and the elasticity test also gives an indication of the accuracy of the flexural strength test this sub-committee will probably make recommendations at the next meeting of the committee that the Tentative Method of Flexure Testing of Slate (D 222 - 27 T) be advanced to standard with the following minor changes:

Section 7. Change the first sentence to read as follows by the addition of the italicized words and the omission of those in brackets:

> The average value of the three specimens cut parallel to the grain shall be reported as the modulus of rupture [parallel] *perpendicular* to the grain, and the average value of the other three, as the modulus of rupture [perpendicular to] *across* the grain.

Section 13. Change the first two sentences to read as follows by the addition of the italicized words and the omission of those in brackets:

> In general the average of the results obtained for the specimens prepared with the length parallel to the grain shall be reported as the modulus of rupture and modulus of elasticity [parallel] *perpendicular* to the grain. Likewise the average results obtained on the specimens cut with the length perpendicular to the grain shall be reported as the modulus of rupture and the modulus of elasticity [perpendicular to] *across* the grain.

These changes are believed to bring about a more logical means of designating the tests with reference to the grain.

The Tentative Method of Test for Water Absorption of Slate (D 221 - 27 T) will require further consideration.

Sub-Committee II on Abrasive Hardness:

The work of Sub-Committee II has consisted chiefly of the development of an apparatus for testing abrasive hardness and will be covered in a paper presented at this annual meeting by D. W. Kessler.[1]

Sub-Committee IV on Electrical Slate:

Attention is called to the fact that in the opening note in the present Tentative Methods of Test for Determining the Insulating Qualities of Slate (D 273 - 27 T),[2] the last sentence reads, "Both Methods (*a*) and (*b*) shall be applied before the slate is drilled" whereas this is in conflict with the first sentence in the note which states that "either method may be used." The committee therefore recommends that the first sentence in the note be altered as follows and the last sentence omitted:

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[1] D. W. Kessler, "The Development of an Apparatus for Wear Tests on Flooring Materials," *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part II, p. 855 (1928).

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 978 (1927); also 1927 Book of A.S.T.M. Tentative Standards, p. 566.

> When it is desired to select slate for specific applications or when a routine factory or shop test is desired, either Method (*a*) or (*b*) may be used, the test being applied before the slate is drilled.

Sub-Committee V on Weathering Characteristics:

At the January meeting of Committee D-16 in New York City, there became available to the committee the last of the series of determinations of atmospheric sulfur. These had been received through the courtesy of Commander Ralph Whitman of the Norfolk Navy Yard which had compiled them in collaboration with the International Nickle Co. and Committee D-14 on Screen Wire Cloth in connection with the exposure tests being conducted by that committee.

These informative records were turned over to Sub-Committee V on Weathering Characteristics with the suggestion that they be made available to others at the Bureau of Standards and particularly to members of committees of the Society working on weathering characteristics of various other materials falling under the jurisdiction of Society committees.

Out of this proffer looking toward cooperation between committees or sub-committees of the Society having to do with weathering characteristics grew the further suggestion that close cooperation in investigations and tests on materials externally employed on buildings or structures subjected to the action of the elements might be effected through exchange of minutes, data, correspondence and other contacts between committees. This interchange of facilities and ideas with respect to weathering characteristics was immediately started by Committee D-16 and the standing committees especially those with interlocking memberships, are now working together on matters connected with weathering characteristics.

The committee has elected the following officers to serve for the ensuing term of two years: W. B. Plank, chairman; Oliver Bowles, vice-chairman; and D. Knickerbacker Boyd, secretary.

This report has been submitted to letter ballot of the committee, which consists of 17 members; 15 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

D. W. KESSLER,
Chairman.

D. KNICKERBACKER BOYD,
Secretary.

REPORT OF COMMITTEE D-17
ON
NAVAL STORES

Melting Point and Viscosity of Rosin

Under date of January 23, 1928, four samples of rosin, together with directions for four different procedures for determining melting point and viscosity were sent to each member of the committee for a study of the methods of determination. The following described samples were used in the work:

Sample No. 1, a composite sample of gum rosin, which was melted in the laboratory at about 125° C., 2.5 per cent of turpentine added to the hot mass which was then thoroughly stirred until of uniform composition, poured, cooled and cut into blocks of about 300 g. each, wrapped in paper and labeled. The sample as finished graded "*K*," close to the "*M*" standard.

Sample No. 2, a composite sample of gum rosin heated in the laboratory at about 145° C. for 45 minutes, stirred until uniform, poured, cooled and cut into blocks of about 300 g. each, wrapped in paper and labeled. This finished sample graded "*H*."

Sample No. 3, "WG" gum rosin made in a fire still, cut into 300-g. blocks as received in the laboratory.

Sample No. 4, a dirty "*H*" grade gum rosin made in a steam still, cut into 300-g. blocks from sample as received in the laboratory, wrapped and labeled in the same manner as the other samples.

Descriptions of the capillary tube method and ring-and-ball method of determining softening point, modified slightly in the light of the tests appear as Appendices I and II to this report. The individual results of each collaborator are given in Table I, and the summary of the results by the capillary tube method and the ring-and-ball method are given in Table II.

Comments of Collaborators

F. P. Veitch (W. C. Smith) (Ring-and-Ball Method).—When samples were melted at about 100° C. they did not adhere to the ring on cooling but dropped out. A temperature of 125° C. is sufficient to melt rosin except crystallized rosin, and when melted at this temperature the poured sample on cooling did not drop out of the ring. If rosin is placed in water at 5° C. it cracks and tests cannot be performed satisfactorily. It was found necessary to place the ring

TABLE I.—COOPERATIVE RESULTS ON MELTING POINT AND SOFTENING POINT OF ROSIN.

	Sample No. 1			Sample No. 2			Sample No. 3			Sample No. 4		
	Capillary Tube Method		Ring-and-Ball Method	Capillary Tube Method		Ring-and-Ball Method	Capillary Tube Method		Ring-and-Ball Method	Capillary Tube Method		Ring-and-Ball Method
	Softening Point, deg. Cent.	Melting Point, deg. Cent.	Softening Point, deg. Cent.	Softening Point, deg. Cent.	Melting Point, deg Cent.	Softening Point, deg. Cent.	Softening Point, deg. Cent.	Melting Point, deg. Cent.	Softening Point, deg. Cent.	Softening Point, deg. Cent.	Melting Point, deg. Cent.	Softening Point, deg. Cent.
F. P. Veitch (W. C. Smith), Bureau of Chemistry and Soils	50	59	72	58	68	79.4	56.6	66.2	78.7	53.5	63.8	75.5
	50	60.2	72.4	58	68.5	80.3	57	66.8	79.1	54	64	76.0
	49	62	72.6	58	68	....	58	66.8	....	54	64.8	....
	49.5	62	72	58.5	69	....	58	67	....	54	64.8	....
Average	49.6	60.8	72.2	58.1	68.5	79.8	57.4	66.7	78.9	53.9	64.4	75.7
F. P. Veitch (K. Ward, Jr.), Bureau of Chemistry and Soils	51.1	54.8	73.2	54.4	66.4	79.2	53	67.2	75.6	56.4	63.9	74.4
	51.2	54.8	76	55.7	65.9	79.7	53.2	66.1	76.3	55.2	64.5	76.3
	49.8	55.9	....	57.2	64.3	....	54.6	65.2	....	55.2	63.7	....
	50.4	53.9	....	60.1	63.9	....	53	65.7	....	55.2	65.6	....
	....	....	....	54	66.1	....	....	....	....	....	....	....
	....	....	....	57.8	64	....	....	....	....	....	....	....
Average	50.6	54.9	74.5	57.4	65.1	79.5	53.4	66.1	75.9	55.5	64.4	75.4
R. C. Palmer, Newport Rosin and Turpentine Co., Pensacola, Fla.	....	....	69.5	....	....	77.5	52.6	....	77.5	....	....	74.5
	....	....	70.5	....	....	78.5	....	....	77.5	....	....	75.0
Average	46.5	54.0	70	54.5	63.4	78	52.6	59.3	77.5	54.2	60.3	74.7
R. C. Palmer, Average[a]	49.5[a]	53.7[a]	....	57[a]	63.2[a]	....	55.5[a]	60.2[a]	....	54[a]	60.2[a]	....
A. M. Johnsen, Pullman Co., Chicago, Ill.	....	....	69	....	....	75.5	....	....	73	....	....	72.5
	....	....	69	....	....	75.5	....	....	73	....	....	73
Average	....	....	69	....	....	75.5	....	....	73	....	....	72.7
E. B. Smith, Jacksonville, Fla., Average	50.5[b]	55.0[b]	70[b]	59.5[b]	66[b]	81[b]	55.5[b]	61[b]	74[b]	56[b]	62[b]	74[b]
R. B. Rohrer (P. W. Smith), Armstrong Cork Co., Lancaster, Pa.	52	56.5	71.0	59	63	79	57	62	76.5	58	63.5	77
	51.5	56	71.0	58.5	63.5	79	57.5	62	77	59.5	63.5	77
	52.5	56.5	71.0	58.5	63.5	79	56.5	62	76.5	....	....	77.5
	....	....	71.5	....	....	79	....	....	76.5	....	....	77.5
Average	52	56.3	71.1	58.7	63.3	79	57	62	76.6	58.7	63.5	77.3
F. J. Arthurs (P. C. Clark), Larkin Co., Inc., Buffalo, N. Y.	53.5	59.5	....	62	66	....	59.8	61.1	....	59	61.8	....
	54	60	....	61	65.2	....	57.5	61.2	....	59	62.2	....
	54	59	....	61.5	65.5	....	59.5	60.8	....	58	61.5	....
	55	59.5	....	61.5	65	....	57	60.5	....	58.5	62	....
Average	54.1	59.5	....	61.5	65.4	....	58.5	60.9	....	58.4	61.9	....
J. E. Lockwood (Kirklin), Hercules Powder Company, Wilmington, Del.	50	....	69.3	54	....	78.8	56	....	76	61	....	75.8
	52	....	69.4	57	....	78.8	57	....	76.2	62	....	75.8
	....	....	69	....	....	78.6	56.5	....	75.8	....	....	75
	....	....	69.2	....	....	78.2	56.5	....	75.8	....	....	75.2
	....	....	70	....	....	78.2	58	....	74.8	....	....	75
	....	....	70.2	....	....	78.4	....	....	74.6	....	....	75.2
	....	....	69.4	....	....	78.4	....	....	74.2	....	....	....
Average	51	60	69.5	55.5	65.0	78.5	56.3	64	75.3	61.5	68.5	75.3
F. L. Roman, Western Electric Co., Inc., Chicago, Ill.	50	54.5	[c]	59	63	[c]	58.5	63	[c]	59	63	[c]
	50	54.5	....	60	64	....	58.5	63	....	59	64	....
	50	54	....	58	62	....	57.5	62	....	58	65	....
	50.5	54.5	....	59.5	64	....	57	62.5	....	58.5	65	....
Average	50	54	....	59	63	....	58	63	....	59	64	....

[a] Newport Capillary Tube Method

[b] Tag Flash-Point Thermometer used in all capillary tube determinations.

[c] Could not keep rosin in ring.

TABLE I.—COOPERATIVE RESULTS ON MELTING POINT AND SOFTENING POINT OF ROSIN (*Continued*).

	Sample No. 1			Sample No. 2			Sample No. 3			Sample No. 4		
	Capillary Tube Method		Ring-and-Ball Method	Capillary Tube Method		Ring-and-Ball Method	Capillary Tube Method		Ring-and-Ball Method	Capillary Tube Method		Ring-and-Ball Method
	Softening Point, deg. Cent.	Melting Point, deg. Cent.	Softening Point, deg. Cent.	Softening Point, deg. Cent.	Melting Point, deg. Cent.	Softening Point, deg. Cent.	Softening Point, deg. Cent.	Melting Point, deg. Cent.	Softening Point, deg. Cent.	Softening Point, deg. Cent.	Melting Point, deg. Cent.	Softening Point, deg. Cent.
P. H. Walker (J. H. Wilson), Bureau of Standards, Washington, D. C.	50	65	71.7	54.5	68	79.6	54	66	76	52.5	68	75.6
	49.5	64.4	71.6	55	69	79.4	53	66	76.2	53	68.5	75.5
Average	50	65	71.6	55	68.5	79.5	53.5	66	76.1	52.8	68.8	75.5
P. H. Walker (H. D. Bruce), Bureau of Standards, Washington, D. C.	....	....	....	59	67	....	....	67	....	53	....	....
	....	....	....	56	65	....	....	....	....	....	....	....
Average	52	56	....	57.5	66	....	55	67	....	53	69	....
E. W. Fasig, Lowe Bros. Co., Dayton, Ohio	51	58.4	....	60	66.5	....	58.5	63	....	56.5	65.5	....
	51.3	58.4	....	60	66.7	....	58.5	63	....	56.8	66.3	....
	51	58.5	....	59.2	66.5	....	58	64	....	57	65	....
	51.2	58.5	....	60	67.5	....	58.3	64	....	57	65	....
	....	....	....	59.5	67.3	....	57.5	63.5	....	....	....	....
	....	....	....	60	....	....	....	64	....	....	....	....
	....	....	....	....	....	....	....	64	....	....	....	....
	....	....	....	....	....	....	....	65	....	....	....	....
Average	51.1	58.5	....	59.8	66.9	....	58.4	63.8	....	56.8	65.5	....
E. V. Romaine, General Naval Stores Co., Cincinnati, Ohio, Average	47.9	55.2	72	55.8	64.3	81.95	53.8	61.3	79.6	54.8	63.5	82.1
C. F. Speh (Dr. Burnett), Pine Institute of America, Inc., Jacksonville, Fla.	53.3	59	67.2	59.3	65.9	76.7	57.5	63.9	72.4	59.7	66.4	....
	53.3	58.3	68	59.3	66.9	77.4	57.5	64.6	74.4	60.6	66.8	....
	53.1	59	....	60.9	66.4	....	56.9	64.2	....	61.0	66.6	....
	53.1	58.8	....	60.4	66.9	....	56.9	63.6	....	61.2	66.6	....
Average	53.2	58.8	67.6	60	66.5	77	57.2	64.1	73.4	60.6	66.6	....
A. R. Hitch, Gillican-Chipley Co., Brunswick, Ga.	51	53	....	59	60.5	....	58	60	....	58	60.5	....
	51	53	....	59	61	....	58	60.5	....	58.5	60.5	....
Average	51	53	....	59	60.8	....	58	60.3	....	58.3	60.5	....
F. W. Hopkins, Murphy Varnish Co., New York, N. Y.	51.5	53	....	57	61.5	....	53.5	57	....	55.3	60	....
	51.5	53	....	57	61.8	....	53.5	57	....	54.5	59	....
Average	51.5	53	....	57	61.7	....	53.5	57	....	54.9	59.5	....
B. E. Kuyers, Tanglefoot Co., Grand Rapids, Mich., Average	56	58	....	63.5	69	....	61	64	....	62	66.5	....
E. J. Johnstone, Paper Makers Chemical Co., Holyoke, Mass.	53	57	79.2	59.5	67	82.7	57	61	79.7	56	63	80.5
	53	57	79.3	60	67	83	57	61	80	57	62.5	81.5
	51	56	79.5	60	67	82.5	57	60.5	80.5	57	63	81.5
	53	57	79.5	59.5	67	83	57	61	80.8	57.4	63.5	81.7
Average	52.5	56.8	79.4	59.8	67.0	82.8	57.	61	80.2	56.9	63	81.3
Highest Average Result	56	65	79.4	63.5	69	82.8	61	67	80.2	62	69	82.1
Lowest Average Result	46.5	53	67.6	54.5	60.0	77	52.6	57	73.0	52.8	59.5	72.7
General Average Result	51.1	56.7	70.6	58.3	65.3	79.3	56.3	62.8	76.4	56.9	64.2	76.2

in the bath at about 25° C. to prevent cracking. There is no practical difference in the melting point results.

F. P. VEITCH (KYLE WARD, JR.) (Ring-and-Ball Method).—The rosin was immersed in the bath at 25° C. instead of 5° C. because of cracking at the lower temperature.

R. C. PALMER (Capillary Tube Method).—Results are submitted by the Newport Capillary Tube Method also, merely to indicate that the capillary tube method is a reliable control procedure even though a variation in the method is introduced. The capillary tube used is $\frac{1}{8}$ in. in inside diameter drawn out at the bottom to about $\frac{3}{4}$ in., tapering to $\frac{1}{32}$ in. inside diameter. The tube is filled with powdered rosin to a depth of 1 in. which gives a rosin sample $\frac{3}{4}$ in. of which tapers from $\frac{1}{32}$ in. to $\frac{1}{8}$ in. and $\frac{1}{4}$ in. of which has a diameter of $\frac{1}{8}$ in. Use a water bath instead of glycerin and start the test at room temperature heating at the rate of 1° C. per minute. The narrow part of the tube is merely used as a control to indicate when the reading should be taken, while the softening point and melting point are observed in the $\frac{1}{4}$-in. length of $\frac{1}{8}$ in. inside diameter.

TABLE II.—SUMMARY OF RESULTS OF TESTS OF SOFTENING POINT AND MELTING POINT OF ROSIN BY DIFFERENT METHODS.

	SAMPLE No. 1, DEG. CENT.	SAMPLE No. 2, DEG. CENT.	SAMPLE No. 3, DEG. CENT.	SAMPLE No. 4, DEG. CENT.
CAPILLARY TUBE METHOD				
SOFTENING POINT:				
Highest Average Value	56	63.5	61	62
Lowest Average Value	49.6	54.5	52.6	52.8
Mean Average Value	51.1	58.2	56.2	56.9
MELTING POINT:				
Highest Average Value	65	69	67	69
Lowest Average Value	53	60	57	59.5
Mean Average Value	56.6	65.2	62.8	64.1
RING AND BALL METHOD				
SOFTENING POINT:				
Highest Average Value	79.4	82.8	80.2	82.1
Lowest Average Value	67.6	77	73	72.7
Mean Average Value	70.6	79.3	76.4	76.2

Results by this procedure are:

	SOFTENING POINT, DEG. CENT.	MELTING POINT, DEG. CENT.
Sample No. 1	49.5	53.7
Sample No. 2	57	63.2
Sample No. 3	55.5	60.2
Sample No. 4	54	60.2

E. B. SMITH.—The special thermometer called for was not available but a standard thermometer from a Tag closed flash point tester was used in all the work calling for a thermometer.

J. E. LOCKWOOD (KIRKLIN) (Capillary Tube Method).—While the capillary tube method gives results which represent as nearly as possible the true melting point of rosin, it is unsuitable for general use because results are greatly influenced by slight changes in procedure. It cannot be used for low melting rosins and waxes, and the size of the sample is so small that it is difficult to make a good determination on a composite sample.

(Ring-and-Ball Method).—Samples were melted at from 110 to 115° C. and poured into the rings at this temperature; after cooling immersed at 20 to 25° C. for 15 minutes and the test carried out as directed. The method has the advantage of having been already adopted as a standard A.S.T.M. test. The apparatus and methods of procedure are simple and determinations can be made rapidly. However, there is the disadvantage of premelting of the sample with consequent loss of volatile matter. With a good many rosins there is a very appreciable loss of volatile matter if melting is carried out at too high a temperature. This loss is usually accompanied by a rise in the softening point, sometimes as much as 5 to 7° C. It is believed that preparation of the sample should be more clearly defined, especially in regard to the temperature at which it is to be melted to pour into the rings and the maximum limit of time which it should be held at this temperature.

F. L. ROMAN (Ring-and-Ball Method).—We were unable to keep the rosin in the ring.

P. H. WALKER (Ring-and-Ball Method).—Difficulty was experienced in preventing the sample from slipping out of the ring due to shrinkage on cooling. It is suggested that the ring be beveled to prevent this.

C. F. SPEH (W. B. BURNETT) (Capillary Tube Method).—It is recommended that a micro-burner be used; that a small hand lens be used for examining the softening and melting point; and that the thermometer used be graduated in fifths.

(Ring-and-Ball Method).—Used an A.S.T.M. thermometer (No. 202). Although the exact directions as given were followed, it is thought that it is not necessary to start with a temperature as low as 5° C. in the case of rosin. Room temperature or even a higher temperature should be just as satisfactory. If any difficulty is experienced in getting the rosin to stick to the inside of the ring, this may be overcome by cleaning the ring with acetone.

A. R. HITCH (Capillary Tube Method).—The results submitted for softening point and melting point on these samples were obtained using our laboratory methods, as given below. The results checked closely to those obtained by the suggested capillary tube method. Our methods, we believe, have the advantage of greater ease of manipulation and ability to handle a large number of samples at once.

Apparatus.—Thermometer, accurate, graduated to 0.1° C., scale 0 to 100.

Glass capillary melting point tubes approximately $\frac{1}{16}$ in. inside diameter and 1.5 in. long.

Electric hot plate.

One 600-cc. Pyrex beaker, one 1000-cc. Pyrex beaker.

Aluminum cylinder containing two ports and of proper diameter to fit conveniently over the 1000-cc. beaker as a shield for viewing the thermometer with an electric light.

Circular rack for supporting 12 glass capillary tubes and a hole in the center for use in supporting a thermometer.

Procedure.—Finely powder the samples of rosin as quickly as possible and put into the glass capillary melting point tubes. (Long rubbing electrifies the powder, makes it become sticky, and causes erratic results). Place the 600-cc. beaker inside the 1000-cc. beaker and partially fill each with water until the water levels coincide. Place the capillary tubes containing the rosin samples in the circular rack and immerse the whole in the water in the center of the 600-cc. beaker. The water should be at a temperature of approximately 40° C. and the levels adjusted to cover the capillaries with the exception of a small portion of the tops. Place the thermometer in the center hole of the rack. Shield the beakers with an aluminum cylinder containing two ports, and fit an electric light bulb to the opposite port from that of the observer's eye to aid in reading the thermometer. Adjust the hot plate to raise the temperature of the water surrounding the capillaries 1° C. per minute.

Softening Point is the temperature at which the rosin in the capillary tubes begins to coalesce.

Melting Point is the temperature at which the rosin in the capillary tubes becomes transparent.

E. J. JOHNSTONE (Capillary Tube Method).—Great care must be exercised in controlling the temperature so that it does not rise at a rate of more than 1° C. per minute. It is difficult to select the correct end point due to gradual change in appearance of rosin. The readings of two operators differ. The method as given gives agreeing results in the hands of one operator only.

(Ring-and-Ball Method).—This method appears best. It is fairly quick and very good checks can be obtained, even by an inexperienced operator. If the rosin is heated too much before pouring it into the rings the final results will be materially affected. By using several rings and balls, determinations can be made very quickly. The apparatus is simple to operate, end point is definite, and very good checks can be obtained.

The collaborative results obtained were thoroughly discussed by the committee at its meeting held on March 23, 1928, in Washington. The capillary tube method and the ring-and-ball method, modified as indicated as necessary by the past year's work, are submitted for publication as information as given in Appendix I and Appendix II to this report for use in determining what the committee voted to designate as the "Softening Temperature" and "Fluid Temperature" of Rosin.

The committee has re-elected the present officers to serve for the ensuing term of two years.

This report has been submitted to letter ballot of the committee, which consists of 18 members; 14 members returned their ballots, of whom 12 have voted affirmatively, 2 negatively, and none has marked his ballot "not voting."

Respectfully submitted on behalf of the committee,

F. P. VEITCH,
Chairman.

C. F. SPEH,
Secretary.

APPENDIX I

PROPOSED METHOD FOR DETERMINATION OF SOFTENING AND FLUID TEMPERATURES OF ROSIN

(Capillary Tube Method)

DEFINITIONS

1. (*a*) *Softening Temperature.*—The temperature at which powdered rosin in a melting point tube begins to darken and coalesce.

(*b*) *Fluid Temperature.*—The temperature at which powdered rosin in a melting point tube loses its powdered or crystallin appearance and becomes wholly transparent.

APPARATUS

2. The apparatus shall consist of the following:

(*a*) *Thermometers* graduated in Centigrade degrees from 45 to 100, be about 5½ in. (137 mm.) long, and about ¼ in. (6 mm.) diameter. Thermometers must be accurate.

(*b*) *Test tubes*, ¾ by 6 in. (20 by 150 mm.) fitted with corks grooved at sides to permit air circulation and bored at center to receive thermometer.

(*c*) *Melting point tubes* of thin glass, inside diameter $\frac{1}{32}$ to $\frac{1}{16}$ in. (0.794 to 1.588 mm.), length 1½ to 2 in., closed at one end and with mouth ⅛ in. in inside diameter.

(*d*) *Flasks*, ordinary Erlenmeyer type of 300-cc. capacity, the mouths of which must be at least 1 in. (25 mm.) in diameter and fitted with a cork grooved at sides to permit air circulation and bored at center to receive test tube.

PROCEDURE

3. Place 250 cc. of glycerin (or water) in the flask, insert the grooved cork carrying the test tube so that its lowest point is ½ in. above the bottom of the flask and heat the flask so that the thermometer rises at the rate of 1° C. per minute above 50° C.

From the freshly broken surface of a lump of the rosin quickly powder a sample (1 to 2 g.) and *at once* fill four melting point tubes to a depth of 10 to 20 mm., lightly packing with a fine glass rod or by tapping. Pass the stem of the thermometer through a cork, grooved to permit air circulation. Attach two of the filled melting point tubes to the thermometer so that the rosin is opposite the bulb. When the temperature of the glycerin (or water) in the flask reaches 45° C. place the thermometer with attached tubes in the test tube suspended in the flask so that its lowest point is ½ in. above the bottom of the test tube. Continue to heat the flask at the rate of 1° C. per minute, note and record the temperature at which the rosin begins to darken and coalesce (softening temperature) and also the temperature at which all the rosin loses its powdered or crystallin appearance and becomes transparent, ignoring air bubbles. The rosin at this temperature is not often fluid enough to fill the bottom portion of the capillary tube and form a meniscus but usually adheres to the side of the tube (fluid temperature). It is necessary during a test to have a light behind the flask, daylight or electric light. Repeat the test using the other two filled melting point tubes making sure that the bath is below 45° C. at the start.

4. The four tests must not vary more than 1° C., otherwise two additional tests must be made and the average reported. The softening temperature tests will probably vary more than the fluid temperature tests. Report the average of each set of results as the softening temperature and fluid temperature, respectively.

APPENDIX II

PROPOSED METHOD OF TEST
FOR
SOFTENING TEMPERATURE OF ROSIN
(Ring-and-Ball Method)

Apparatus

1. The apparatus shall consist of the following:

(*a*) *Ring.*—A brass ring 15.875 mm. ($\frac{5}{8}$ in.) in inside diameter and 6.35 mm. ($\frac{1}{4}$ in.) deep; thickness of wall, 2.38 mm. ($\frac{3}{32}$ in.); permissible variation on inside diameter and thickness of ring 0.25 mm. (0.01 in.). This ring shall be attached in a convenient manner to a No. 13 B. & S. gage brass wire (diameter 1.83 mm. = 0.072 in.). See Fig. 1.

(*b*) *Ball.*—A steel ball 9.53 mm. ($\frac{3}{8}$ in.) in diameter weighing between 3.45 and 3.55 g.

(*c*) *Container.*—A glass vessel, capable of being heated, not less than 8.5 cm. (3.34 in.) in diameter and measuring 10.5 cm. (4.13 in.) in depth from the bottom of the flare. (A 600-cc. beaker, low form, meets this requirement.)

(*d*) *Thermometer.*—A thermometer which shall conform to the following requirements. These specifications cover a special thermometer graduated in either Centigrade or Fahrenheit degrees as specified, the ranges being 0 to 80° C. or 30 to 180° F., respectively.

Type: Etched stem, glass.

Liquid: Mercury.

Range and Subdivision: −2 to +80° C. in 0.2° C. or +30 to +180° F. in 0.5° F.

Total Length: 378 to 384 mm. (14.88 to 15.12 in.).

Stem: Plain front, enamel back, suitable thermometer tubing. Diameter, 6.0 to 7.0 mm. (0.24 to 0.28 in.).

Bulb: Corning normal or equally suitable thermometric glass.
Length, 9 to 14 mm. (0.35 to 0.55 in.).
Diameter, 4.5 to 5.5 mm. (0.18 to 0.22 in.).

Distance to 0° C. or 32° F. Line from Bottom of Bulb: 75 to 90 mm. (2.95 to 3.54 in.).

Distance to 80° C. or 176° F. Line from Top of Thermometer: 30 to 45 mm. (1.18 to 1.77 in.).

Expansion Chamber: To permit heating the thermometer at least 50° C. (90° F.) above highest temperature on scale.

Filling above Mercury: Nitrogen gas.

Top Finish: Glass Ring.

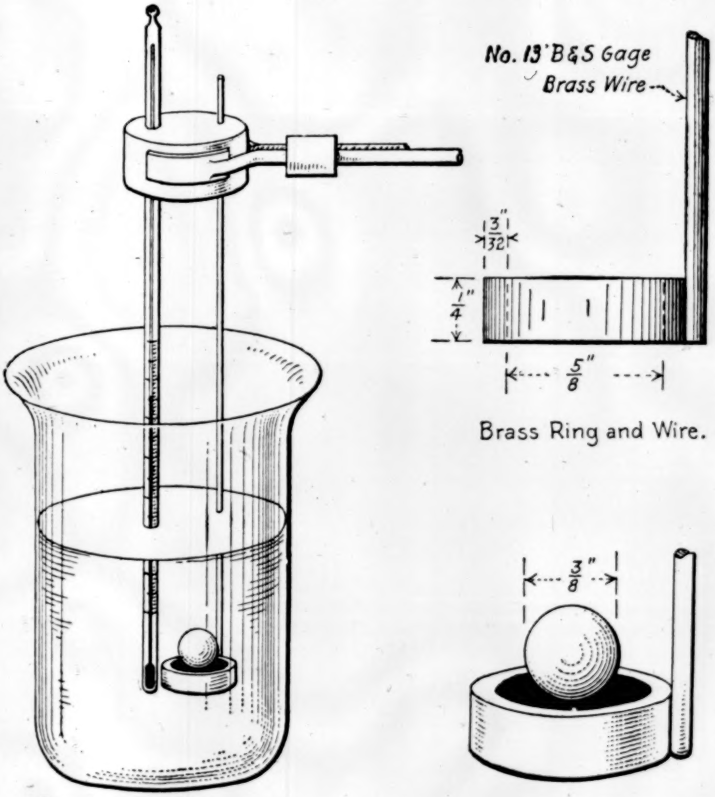
Graduation: All lines, figures, and letters clear cut and distinct. Each whole degree Centigrade or Fahrenheit line to be longer than the remaining lines. Graduations to be numbered at each multiple of 2° C. or 5° F.

Immersion: Total.

SPECIAL MARKING: "A.S.T.M. Low S.P.," a serial number and the manufacturer's name or trade mark shall be etched on the thermometer.

SCALE ERROR: The error at any point of the scale when the thermometer is standardized as provided below shall not exceed 0.2° C. or 0.4° F.

STANDARDIZATION: The thermometer shall be standardized immersed in the testing bath to the top of the mercury column, at the ice point and at temperature intervals of approximately 20° C. or 40° F.



Brass Ring and Wire.

Assembly of Apparatus.

Proper Position of Ball.

FIG. 1.—Apparatus for Ring-and-Ball Method.

CASE: The thermometer shall be supplied in a suitable case on which shall appear the marking: "A.S.T.M. Low S.P., 0 to 80° C.," or "A.S.T.M. Low S.P., 30 to 180° F." according to the type of thermometer.

NOTE.—For the purpose of interpreting these specifications the following definitions apply:

The total length is the over-all length of the finished instrument.

The diameter is that measured with a ring gage.

The length of the bulb is the distance from the bottom of the bulb to the beginning of the enamel backing.

The top of the thermometer is the top of the finished instrument.

PREPARATION OF SAMPLE

2. *Preparation of Sample.*—Place about 25 g. of the freshly broken rosin in a low 50-cc. beaker, insert a thermometer, cover with watch glass, and immerse in a suitable bath kept at 125° C. As soon as the well-stirred mass of rosin in the beaker has reached 125° C. remove beaker from bath and at once fill four rings, pouring the rosin into the ring so as to leave an excess on cooling. The ring, while being filled, should rest on a brass plate which has been amalgamated to prevent the rosin from adhering to it. After cooling, the excess material shall be cut off cleanly with a slightly heated knife.

PROCEDURE

3. *Assembling.*—Fill the glass vessel to a depth of substantially 8.25 cm. (3.25 in.) with freshly boiled, distilled water at room temperature. Suspend the ring containing the sample in the water so that the lower surface of the filled ring is exactly 2.54 cm. (1 in.) above the bottom of the glass vessel and its upper surface is 5.08 cm. (2 in.) below the surface of the water. Place the ball in the water but not on the specimen. Suspend the thermometer so that the bottom of the bulb is level with the bottom of the ring and within 0.635 cm. ($\frac{1}{4}$ in.), but not touching the ring. Maintain the water at room temperature for 15 minutes. With suitable forceps, place the ball in the center of the upper surface of the rosin in the ring, thus completing the assembly as in Fig. 1.

4. *Heating.*—Apply the heat in such a manner that the temperature of the water is raised 5° C. (9° F.) each minute.

5. *Softening Point.*—The temperature recorded by the thermometer at the instant the rosin touches the bottom of the glass vessel shall be reported as the softening point. No correction shall be made for emergent stem.

6. *Permissible Variation in Rise of Temperature.*—The rate of rise of temperature shall be uniform and shall not be averaged over the period of the test. The maximum permissible variation for any minute period after the first three shall be ±0.5° C. (0.9° F.). All tests in which the rate of rise in temperature exceeds these limits shall be rejected.

PRECAUTIONS

7. *Precautions.*—The use of freshly boiled distilled water is essential, as otherwise air bubbles may form on the specimen and affect the accuracy of the results. Rigid adherence to the prescribed rate of heating is absolutely essential in order to secure accuracy of results.

A sheet of paper placed on the bottom of the glass vessel and conveniently weighted will prevent the rosin from sticking to the glass vessel, thereby saving considerable time and trouble in cleaning.

ACCURACY

8. *Accuracy.*—The limit of accuracy of the test is ±0.5° C. (0.9° F.).

REPORT OF COMMITTEE D-18
ON
NATURAL BUILDING STONES

At the last annual meeting of the Society, Committee D-18 on Natural Building Stones presented a brief report, outlining the chief reasons for organizing this standing committee, based primarily upon the need for a broader and more complete knowledge of building stone, its characteristics and physical properties and behavior under various conditions of usage, to enable architects and engineers to design for and use it in the most practical, safe and economical manner in modern buildings; the history of the committee's formation and the program adopted to govern its activities, making specific reference to the preparation of a bibliography of the available data on building stones, their properties and weathering qualities, as developed under the various conditions of actual usage in the walls of buildings, as well as by tests and analysis.

Since the compilation of that bibliography and a study of existing data were the first steps in the development of the committee's work, and quite necessary as preliminary to the formulation of any test program, the committee has been obliged to mark time while this work was being done, and, therefore, did not find it advisable to hold any meetings during the past year other than the meeting held in connection with this annual meeting of the Society.

The committee is pleased to report good progress as follows:

The necessary funds for the completion of the bibliography data were subscribed by its several producer interests, and the bibliography completed under the direction of Mr. G. F. Loughlin, chairman of the Data Sub-Committee. The cross-indexing and mimeographing of the bibliography has now been provided for and will proceed at once. When completed this will furnish all members of the committee with copies for ready reference and study.

A brief review or summary of the work of the Data Sub-Committee has been prepared, and while filed at the headquarters of the Society as a matter of record, is not considered essential for inclusion in this report.

A temporary sub-committee appointed to study the methods of test now in use has been at work and the existing test methods for the determination of the physical properties of building stone have been considered in a preliminary way. During the coming year the more important methods of testing procedure will be written up in complete form for study and consideration by the committee, with a view toward selecting, amplifying and submitting certain of these methods to the Society as tentative standards, at the next annual meeting. The temporary committee on methods of test, as it was designated at the time of its appointment, has now been made a permanent Sub-Committee on Testing Procedure.

The Sub-Committee on Scope also held a meeting and recommends augmenting the program of Committee D-18 to include another sub-section on uniform cubing of stone, which recommendation was approved by the committee and a sub-committee appointed to handle this work composed of representatives of the four branches of the stone industry now participating in the work of Committee D-18—granite, limestone, sandstone and marble.

During the year, certain basic definitions pertaining to the stone industry were prepared. These were first reviewed by the Data Sub-Committee and then by the entire committee, and as revised and amended by these two conferences will soon be ready for submission to Committee E-8 on Nomenclature and Definitions as the first installment of definitions applying to the work of Committee D-18.

The committee is pleased to report further that one of its member producing interests has recently under its research program taken up two important studies—one a comprehensive series of long-time temperature change studies and the other a thorough study of the relative merit of the elastic caulking materials, of the types customarily recommended for and used in connection with masonry walls.

An election of officers was held resulting in the re-election of the following officers to serve for the ensuing two years: F. Y. Joannes, chairman; W. M. Grieg, vice-chairman, and H. S. Brightly, secretary.

Respectfully submitted on behalf of the committee,

F. Y. JOANNES,
Chairman.

H. S. BRIGHTLY,
Secretary.

REPORT OF COMMITTEE E-1
ON
METHODS OF TESTING

Ever since its reorganization in 1920, Committee E-1 on Methods of Testing has stressed the importance of giving more careful consideration to the preparation of methods of test. This applies equally to the method of describing the procedure for carrying out a test and to the principles underlying the test. It is important that a method of test be basicly sound. It is equally important that once a decision has been reached that a given determination is significant, the procedure for making this determination be clearly set forth, complete in all details. The need for being explicit in descriptions of methods was ably discussed in 1926 by the retiring President, Mr. W. H. Fulweiler in his Presidential Address on "The Importance of Little Things in the Standardization of Methods of Testing."[1] Most determinations are in a sense empirical in that the results obtained in carrying out the test procedure are largely dependent upon the conditions of the test.

It was with this in mind that Committee E-1 submitted a number of recommendations covering the preparation of methods of test which were published in the annual reports of Committee E-1 for 1925[2] and 1926.[3] It is essential that a test procedure be set forth clearly and explicitly. It is also desirable that a statement be included indicating what the test is intended to determine and its general applicability and also to give any limitations that the test may have. It is also important to indicate the accuracy of a test and the degree of reproducibility that may be expected.

It is one of the functions of Committee E-1 to review the various test procedures to see that they are complete in these respects. Such a review is essentially one of an editorial nature, and as such is handled largely by the Editorial Committee of Committee E-1 or by the technical committees organized to study specific groups of methods of testing. Considerable progress in making these editorial reviews has been made by the committee during the past year. Methods of test have been adopted by the Society in such increasing numbers during the past few years that the task of reviewing them is becoming one of considerable magnitude. On the other hand, this task is made somewhat easier by the fact that committees have responded to the suggestions of Committee E-1 and have prepared test procedures in more complete fashion and with greater care. Revisions in existing test procedures have also been made to bring them in line with the recommendations of Committee E-1.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, p. 39 (1926).

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 25, Part I, p. 398 (1925).

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, p. 502 (1926).

As a matter of detail in handling this work, it is proposed by the Editorial Committee that where only one description of the method is involved this description be scanned to see that it conforms with the principles laid down by Committee E-1 and if it appears to be complete in all details and set forth in a clear manner, it is proposed that these procedures be given the formal approval of Committee E-1. Where two or more descriptions of the same method appear in the standards of the Society, it is proposed to make a detailed comparison of these descriptions and on the basis of this comparison a description will be prepared and submitted to the standing committees concerned for comment. If acceptable to these committees, the standards in question should be suitably revised and the method submitted to the membership of Committee E-1 for approval.

When comparisons made by the Editorial Committee indicate the desirability of a general description being prepared as a separate document, one which could be incorporated by reference in other standards, the Editorial Committee would, of course, need to turn to the standing committees concerned for advice on the preparation of such a general method. In some instances, it will become apparent that the consideration of the methods could best be handled by a technical committee of Committee E-1, and steps would then be taken for the organization of such a group. The procedures outlined above give promise of making it possible to have all the methods of the Society reviewed and approved by Committee E-1 during the next few years. It has already led to the organization of at least one technical committee, namely, that on Methods of Test for Density, and a review of a number of descriptions of individual methods is already well advanced. The study of the fundamentals underlying methods of test has also proceeded in a very satisfactory manner in the activities of the various technical committees and very substantial progress is being reported by these committees this year.

Committee E-1 is essentially a correlating committee. This is evident from the nature of the review work which the Editorial Committee is carrying on, comparing the procedure for a given test submitted by one standing committee with that of a similar procedure submitted by some other standing committee. It is also evident from much of the work of the technical committees, since after completing a study of the fundamentals underlying a test each technical committee proposes to review all descriptions of methods falling within its scope. Committee E-1 must look on methods of test from an academic viewpoint. It is a cross-section committee and, as such, is not interested so much in determining which specific test may be applicable to any given product, but in the study of types of tests from a broad viewpoint and to see that each is fundamentally sound. It is in a position, of course, to lend advice to standing committees through its working groups or sections concerning given types of tests.

Index of Methods of Testing.—In view of its function as a correlating committee, to secure uniformity and agreement in descriptions of the same or similar determinations put out by standing committees, the committee feels that an index of methods of testing, to supplement the indexes now appearing in the Book of Standards and Book of Tentative Standards, would be helpful. Standing committees sometimes find need for a procedure for making a given determination and, without appreciating that a similar procedure may have been prepared by another standing committee, they will proceed to prepare a new method of test. With an index readily available of all methods that may have been issued of a given type, the committee may find one of these methods will serve its purpose or, if not directly applicable, may afford some very helpful suggestions. Committee E-1 accordingly proposes to issue such an index of methods of test, covering both standard and tentative methods, the index to become available in mimeographed form during the next few months. This will be furnished to the representatives of standing committees serving on Committee E-1 and to committee officers and to other members of the Society upon request.

ACTIVITIES OF TECHNICAL COMMITTEES

No recommendations are offered this year concerning actions on standards or tentative standards. This is not to be considered in any sense as a lack of activity on the part of the technical committees. They have for the most part been engaged in fundamental studies preparatory to making any definite recommendations. The organization of working groups has been continued. The formation of nucleus groups, consisting of those especially interested in any given type of test, has proved to be particularly effective. Serving with these specially qualified individuals are representatives of the standing committees concerned and other members of the Society who may serve as unofficial members of the section should they so desire. The activities of the several technical committees during the year is outlined below.

Technical Committee I on Mechanical Testing (H. F. Moore, chairman).—The Technical Committee on Mechanical Testing reports the organization of additional sections, so that the committee has now functioning Sections on Tension Testing, Compression Testing, Flexure Testing, Bend Tests for Ductility and on the Testing of Thin Sheet Metals. The Section on Bend Tests for Ductility was but recently organized, under the chairmanship of A. B. Kinzel. It has held an organization meeting and has made an excellent start in planning its work. The Section on Testing Thin Sheet Metals, under the chairmanship of H. C. Knerr, is now considering speeds for testing and grips for holding specimens. A special group, under the chairmanship of J. R. Townsend, has been asked to study test methods for hardness other than the Brinell test, and has submitted a preliminary report on standard methods for making the Rockwell test.

Special matters awaiting the consideration of the technical committee are calibration methods for cement-testing machines and allowable speeds of loading for hydraulically operated testing machines.

Technical Committee II on Impact Testing (E. B. Smith, chairman).—This technical committee reports the organization of a nucleus group of individuals definitely engaged in impact testing, for the purpose of developing the test, as follows:

E. B. Smith
R. L. Templin
H. L. Whittemore
John M. Lessells
Walter W. Werring
Everett S. Lee
L. W. Teller

This group is not intended to replace the present Committee on Impact Testing but to serve as a small group closely connected with impact testing to collect results for the consideration of the committee.

A request for information concerning the present status and use of the impact test resulted in replies indicating that several laboratories are doing some very intensive work on the development of the impact test. A few are working on the fundamentals of the test which seem to provide some definite solutions to impact test problems.

Technical Committee III on Plasticity, Consistency, Etc. (E. C. Bingham, chairman).—The report of the Technical Committee on Plasticity, Consistency, Etc. is appended hereto. This report represents a considerable step forward in arriving at definitions for the basic concepts underlying the work of the technical committee. The report had received considerable publicity prior to its adoption by the technical committee and its submission to Committee E-1. In it the following definitions are offered as information in order to elicit comments and suggestions that may be helpful to the technical committee in its further deliberations:

> *Consistency* is that property of a material by which it resists permanent change of shape and is defined by the complete flow-force relation. If in non-turbulent flow the ratio of flow to force is constant, the material is said to be fluid, otherwise it is plastic.
>
> *Plasticity* is that property of a material by which, as the shearing stress is lowered, the material resists change of shape relatively more than in the case of a fluid; thus for a plastic material the ratio of flow to force is not constant.

Technical Committee IV on Size and Shape (J. P. Hubbell, chairman).—This technical committee has assigned its work to three sections: the Section on Coarse Screens under the chairmanship of F. H. Jackson, the Section on Fine Screens under the chairmanship of J. P. Hubbell, and the Section on Sub-Sieve Sizes under the chairmanship of J. P. Hubbell. The Section on Fine Screens has nothing further to report other than that an attempt is being made to prepare a standard method of making mechanical analyses by means of sieves.

The report of the Section on Coarse Screens is appended hereto. The section was organized to effect, if possible, some unification in the use of screens having openings larger than No. 4. There is at present no agreement as to whether square-mesh or round openings should be used in making mechanical analyses of relatively coarse materials. This lack of agreement is responsible for considerable confusion.

The present report discusses an attempt that has been made to determine whether one type of screen showed advantage over the other as regards accuracy. A series of tests had been carried out with that in view. The results of these tests showed that neither type showed any advantage over the other, that errors due to sampling overshadowed differences due to shape of opening. Based upon other considerations the section recommends the round-hole screen as a standard type for testing granular materials, any change in the present standards to become effective by 1930. This recommendation will receive the consideration of Committee E-1 during the year and will be brought to the attention of the standing committees concerned for comment.

The report of the Section on Sub-Sieve Sizes is appended hereto. Much of the work of this section has been handled by C. S. Haslam of the New Jersey Zinc Co. under the direction of the chairman, J. P. Hubbell. Mr. Hubbell is relinquishing the chairmanship of the section and has designated Mr. Haslam as chairman. The report discusses the work of the section during the past two years, during which time a comprehensive series of tests has been carried out on nine samples of material ranging in size from that passing a 75-micron opening sieve to that too fine to be resolved under a compound microscope.

Technical Committee V on Methods for Density (A. T. Goldbeck, chairman).—The report of this technical committee, comprising a program which the committee proposes to follow in reviewing the methods for specific gravity, density, etc. and discussing some of the problems involved in these tests, is appended hereto.

Technical Committee VII on Volatility.—This technical committee has been under the chairmanship of A. W. Dow, a member of the Advisory Committee. Mr. Dow recently resigned as a member of the Advisory Committee and has accordingly relinquished the chairmanship of the technical committee. Considerable work has been carried out during the past year on the distillation test in Committee D-4 on Road and Paving Materials and this committee is now undertaking a study of the test for loss on heating.

Technical Committee VIII on Chemical Composition (G. E. F. Lundell, chairman).—The Technical Committee on Chemical Composition recently effected organization. The committee proposes to function along the lines of a committee on Chemical Composition of the American Chemical Society, and will pass upon methods of chemical analysis before these are advanced to standard.

The committee has elected the following officers to serve for the ensuing term of two years: W. H. Fulweiler, chairman; H. F. Moore, vice-chairman.

The committee submitted the several reports appended hereto to letter ballot, with the following results; the committee consists of 45 members, 34 members returned their ballots:

Items	Affirmative	Negative	Not Voting
PUBLICATION AS INFORMATION IN REPORT OF COMMITTEE E-1			
1. Report of Technical Committee III on Plasticity, Consistency, Etc.	32	0	2
2. Report of Technical Committee V on Methods for Density	31	0	3
3. Report of Section on Coarse Screens	31	0	3
4. Report of Section on Sub-Sieve Sizes	32	0	2

This report has been submitted to letter ballot of the committee, which consists of 45 members; 32 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

R. E. HESS,
Ex-Officio Secretary.

J. A. CAPP,
Chairman.

REPORT OF TECHNICAL COMMITTEE III ON PLASTICITY, CONSISTENCY, ETC.

The properties of matter involving flow are very diverse and many of the terms used do not even suggest that flow is involved. Such properties are ductility, hardness, solubility, melting point and shortness, as well as the more obvious properties of flow, such as consistency, plasticity and viscosity. It is assumed that only a few fundamental properties of matter are involved in the flow and that these can eventually be expressed in absolute units. It has been suggested that such fundamental properties may be:

Fluidity, ϕ, the reciprocal of viscosity, η, for fluids only;

Mobility, μ, the reciprocal of some property, ζ, which denotes the stiffness or immobility of the material;

Yield value, f, and ultimate strength, I; and

Elasticity, e, the reciprocal of the rigidity, r.

If these properties are the fundamental properties of flow, it would be desirable to relate the properties used in practice to these which appear to be more fundamental and expressible in absolute units. We may assume that further study may introduce yet other properties of flow, but these have been suggested. The above properties may be defined in a later report.

Consistency and Plasticity:

It appears that neither consistency nor plasticity can be considered as a fundamental property to which a numerical value can be given, but on the other hand both are complex properties for which the following definitions are submitted for publication as information:

> *Consistency* is that property of a material by which it resists permanent change of shape and is defined by the complete flow-force relation. If in non-turbulent flow the ratio of flow to force is constant, the material is said to be fluid, otherwise it is plastic.
>
> *Plasticity* is that property of a material by which, as the shearing stress is lowered, the material resists change of shape relatively more than in the case of a fluid; thus for a plastic material the ratio of flow to force is not constant.

There are various types of plastic flow. There are also many factors which affect the flow, such as temperature, concentration, size and shape of particle and adhesion between particles, but they are not considered as fundamental properties of flow. Three types of deformation are given as illustrative:

Elastic Deformation, s, $= eFd$

Rate of *Fluid Deformation*, $v = \phi F d$

Rate of *Plastic Deformation* $v = \mu(F - f)d$

where s = distance;
v = velocity;
F = shearing stress;
d = thickness of the deformed material;
e = elasticity;
ϕ = fluidity;
μ = mobility;
f = yield shear value.

Respectfully submitted on behalf of the sub-committee,

E. C. BINGHAM,
Chairman.

REPORT OF SECTION ON COARSE SCREENS

The Section on Coarse Screens, of Technical Committee IV on Size and Shape, was organized approximately one year ago by Committee E-1 for the purpose of studying the question of the shape of aperture to be employed in coarse screens used for testing purposes. The Section has held two meetings, one at the time of the annual meeting of the Society at French Lick, Ind., and the other at Washington, D. C., on March 22, 1928. The committee herewith presents a brief discussion of its work to date, together with such recommendations as it has been possible to make up to the present time.

Discussion of Present Situation

At the present time screens for the determination of size of coarse granular materials, such as crushed stone, gravel, blast-furnace slag, coal and ores, are of two general types—those employing circular openings and those employing square openings. In the road building field the round-hole screens are used almost exclusively in specifying sizes of aggregates for various types of road construction. This is reflected in the fact that there are at present 12 standard and tentative specifications for broken stone and broken slag for road construction, all of which specify sizes on the basis of the round hole screen. There are in addition two tentative specifications for commercial sizes, one covering broken stone and broken slag (D 63 – 23 T) and the other gravel (D 64 – 20 T). The Society also has a Standard Method of Mechanical Analysis of Broken Stone or Broken Slag, Except Aggregates Used in Cement Concrete (D 18 – 16) as well as a Standard Method of Mechanical Analysis of Mixtures of Sand or Other Fine Material with Broken Stone or Broken Slag, Except Aggregates Used in Cement Concrete (D 19 – 16). There is also a Standard Form of Specification for Certain Commercial Grades of Broken Stone (D 35 – 18) based on round hole screens.

As regards aggregates for concrete, a survey of the field indicates that in so far as the state highway departments are concerned 7 states employ square-mesh sieves for the determination of size, and all others employ round-hole screens. A survey of city specifications for concrete shows 7 cities specifying square openings and 11 round openings. On the other hand, the Society's Standard Method of Test for Sieve Analysis of Aggregates for Concrete (C 41 – 24) specifies square-mesh sieves. Certain organizations, moreover, specify sizes on the basis of square-mesh sieves in connection with the design of concrete mixtures by the fineness modulus method.

In connection with the determination of size of coal, a study of the situation indicates that round-hole screens are used exclusively in the anthracite coal industry for the determination of size. The use of a definite type of screen for sizing bituminous coal and coke has not yet become standard; however, the methods of test for sieve analysis of these materials proposed by Committee D-5 on Coal and Coke of the Society provide for the use of square-mesh sieves.

In the field of ore dressing, the prevailing practice seems to be to use sieves with square openings for classifying sizes up to 1 in. Considerable work has been done in this field in the study of efficiency of different methods of crushing ores, and a large amount of data accumulated on the basis of the use of square-mesh sieves.

OUTLINE OF THE WORK OF THE COMMITTEE

At the French Lick meeting the various matters outlined above were thoroughly discussed, and it was decided that for the present the standardization efforts of the committee should be restricted to the field of mineral aggregates. For this purpose, the committee drew up a series of tests to be made by three cooperating laboratories on five typical aggregates, such as crushed stone, gravel and slag, for the purpose of determining (*a*) which type of opening gives the most concordant results on repeated tests on the same samples and for various types of aggregates ranging from those substantially spherical in shape to those containing a large portion of flat elongated pieces, and (*b*) whether any consistent relationship exists between the amount passing a round-hole screen and the amount passing a corresponding square-mesh opening sieve.

This work was duly carried out by the three cooperating laboratories representing the Portland Cement Association, the Standard Slag Co., and the U. S. Bureau of Public Roads. The results obtained are presented as part of this report in Tables I to VIII, inclusive. Tables I to III, inclusive, give the results of sieve analyses by the three laboratories of each of the five materials, using both round and square openings. The procedure employed by each laboratory was as follows: The entire sample of each of the materials was piled on a flat surface and thoroughly mixed. A test sample of between 25 and 50 lb. was then removed from the pile by the standard method of quartering and a mechanical analysis made on this sample, first using the round-hole screens and then the square-mesh sieves. At the conclusion of the analysis this test sample was temporarily discarded and another

TABLE I.—RESULTS OF COMPARATIVE MECHANICAL ANALYSES OF COARSE AGGREGATES BY PORTLAND CEMENT ASSOCIATION.

Screen	Total Retained on Each Screen, per cent											
	Round Openings						Square Openings					
	Sample A			Sample B			Sample A			Sample B		
	First Determination	Second Determination	Third Determination	First Determination	Second Determination	Third Determination	First Determination	Second Determination	Third Determination	First Determination	Second Determination	Third Determination
						GRAVEL						
2½ in.	..	..	..	..	..	..	..	..	..	..	..	..
2 in.	2	4	1	0	0	3	..	..	..	..	..	..
1½ in.	13	12	14	16	16	12	8	6	5	8	5	5
1 in.	45	37	50	49	44	43	36	26	38	38	33	31
¾ in.	59	54	66	63	58	63	53	46	61	59	53	55
½ in.	77	78	84	80	79	82	68	67	75	71	80	73
¼ in.	98	99	99	99	98	99	93	95	97	94	94	96
						LIMESTONE						
2½ in.	2	2	0	3	3	4	..	..	..	..	..	..
1 in.	7	8	12	10	11	13	4	2	0	0	5	4
½ in.	15	20	20	23	17	17	10	12	12	12	13	17
1 in.	23	33	33	34	27	30	19	24	25	27	19	23
¾ in.	42	53	54	56	46	49	30	39	41	44	34	36
½ in.	69	86	84	82	77	79	54	72	69	69	61	62
¼ in.	97	98	99	99	97	99	91	96	96	96	92	96
						TRAP						
2 in.	..	..	..	..	..	..	..	..	..	..	..	..
1½ in.	14	11	9	12	13	12	3	1	3	3	3	5
1 in.	39	35	38	41	38	36	28	23	28	31	27	27
¾ in.	55	50	53	55	53	51	45	40	42	45	42	42
½ in.	79	78	82	80	79	77	63	63	66	64	64	62
¼ in.	99	98	99	98	99	98	95	93	96	94	95	94
						SLAG						
2 in.	..	..	..	..	..	..	..	..	..	..	..	..
1½ in.	3	5	5	5	6	2	1	0	0	0	0	0
1 in.	28	34	28	26	35	28	19	29	21	19	27	21
¾ in.	54	55	50	46	54	52	41	45	38	33	44	40
½ in.	78	80	74	73	75	77	69	71	63	62	68	66
¼ in.	98	99	99	98	98	99	94	95	94	94	93	94
						GNEISS						
3 in.	0	3	3	3	4	0	0	0	0	0	0	0
2½ in.	12	18	14	13	11	7	..	..	..	..	..	..
2 in.	31	32	27	26	27	18	8	17	9	13	12	6
1½ in.	45	50	44	42	49	36	34	36	29	31	34	25
1 in.	69	71	69	68	75	59	58	60	55	56	64	49
¾ in.	86	85	86	86	89	77	79	77	78	78	82	67
½ in.	97	95	97	96	98	94	93	90	93	92	94	86
¼ in.	99	98	99	99	100	98	99	97	99	98	99	97

TABLE II.—RESULTS OF COMPARATIVE MECHANICAL ANALYSES OF COARSE AGGREGATES BY STANDARD SLAG CO.

Screen	Total Retained on Each Screen, per cent											
	Round Openings						Square Openings					
	Sample A			Sample B			Sample A			Sample B		
	First Determination	Second Determination	Third Determination	First Determination	Second Determination	Third Determination	First Determination	Second Determination	Third Determination	First Determination	Second Determination	Third Determination
Gravel												
$2\frac{1}{2}$ in.	0	0	0	0	0	0	..	..	..	..	..	..
2 in.	3	2	2	2	1	3	0	0	0	0	0	0
$1\frac{1}{2}$ in.	19	18	17	16	17	18	9	8	6	7	5	9
1 in.	55	51	52	50	55	54	41	36	39	35	41	39
$\frac{3}{4}$ in.	69	64	64	65	66	65	64	59	60	61	62	60
$\frac{1}{2}$ in.	85	83	79	84	83	82	77	74	71	77	75	73
$\frac{1}{4}$ in.	99	99	99	99	99	99	96	96	93	95	96	96
Limestone												
$2\frac{1}{2}$ in.	2	2	3	4	3	1	0	0	0	0	0	0
2 in.	6	7	9	10	11	6	1	2	4	3	5	1
$1\frac{1}{2}$ in.	21	19	29	25	24	23	15	10	20	15	20	15
1 in.	33	29	42	39	34	35	25	22	31	30	29	25
$\frac{3}{4}$ in.	54	54	62	62	59	56	42	37	49	50	46	42
$\frac{1}{2}$ in.	81	84	87	87	87	86	69	67	74	74	73	71
$\frac{1}{4}$ in.	98	98	99	98	98	99	95	96	96	96	96	96
Trap												
2 in.	1	0	2	3	2	3	0	0	0	0	0	0
$1\frac{1}{2}$ in.	17	17	18	16	19	21	7	6	7	6	5	8
1 in.	48	42	49	47	49	47	35	27	33	33	34	33
$\frac{3}{4}$ in.	63	57	62	62	64	62	54	47	53	53	55	51
$\frac{1}{2}$ in.	87	81	85	86	87	87	78	67	73	74	74	75
$\frac{1}{4}$ in.	99	99	99	99	99	99	98	95	96	97	97	97
Slag												
2 in.	0	0	0	0	0	0	..	..	..	..	..	..
$1\frac{1}{2}$ in.	7	6	8	6	5	9	1	1	1	1	0	1
1 in.	33	38	34	30	28	38	26	29	25	24	21	28
$\frac{3}{4}$ in.	51	58	57	53	49	58	42	48	46	44	40	46
$\frac{1}{2}$ in.	80	82	83	77	79	83	68	72	75	69	69	74
$\frac{1}{4}$ in.	99	99	99	99	99	99	96	96	98	96	96	96
Gneiss												
3 in.	4	1	0	3	3	1	..	..	..	..	..	..
$2\frac{1}{2}$ in.	18	10	11	9	18	8	..	..	..	..	..	..
2 in.	34	21	26	27	38	23	21	9	9	8	20	11
$1\frac{1}{2}$ in.	53	41	46	49	52	39	42	40	33	35	44	29
1 in.	68	69	70	77	71	62	59	49	56	64	59	49
$\frac{3}{4}$ in.	83	88	85	91	86	83	74	80	76	83	77	73
$\frac{1}{2}$ in.	95	98	97	98	97	96	91	94	91	95	93	91
$\frac{1}{4}$ in.	98	99	99	99	99	99	98	99	98	99	99	98

TABLE III.—RESULTS OF COMPARATIVE MECHANICAL ANALYSES OF COARSE AGGREGATES BY U. S. BUREAU OF PUBLIC ROADS.

Screen	Total Retained on Each Screen, per cent											
	Round Openings						Square Openings					
	Sample A			Sample B			Sample A			Sample B		
	First Determination	Second Determination	Third Determination	First Determination	Second Determination	Third Determination	First Determination	Second Determination	Third Determination	First Determination	Second Determination	Third Determination
GRAVEL												
2½ in.	0	0	0	0	0	0	..	..	..	..	..	..
2 in.	3	3	1	2	4	5	..	..	..	..	..	..
1½ in.	20	17	14	16	19	23	9	7	7	8	10	10
1 in.	49	49	44	46	52	51	36	35	30	33	38	40
¾ in.	68	65	61	64	69	68	59	58	52	56	62	60
½ in.	83	82	80	81	85	84	75	73	70	73	77	76
¼ in.	99	99	99	99	99	99	95	95	95	95	97	96
LIMESTONE												
2½ in.	3	0	2	2	2	1	..	..	..	..	..	..
2 in.	15	14	12	11	13	13	6	2	1	5	2	2
1½ in.	29	26	27	25	26	27	19	17	19	16	16	20
1 in.	38	37	37	34	36	38	31	29	29	28	29	31
¾ in.	59	60	57	56	56	59	43	42	41	40	41	42
½ in.	81	84	81	79	81	81	67	70	68	67	68	70
¼ in.	99	99	99	98	99	98	94	95	94	93	95	94
TRAP												
2 in.	1	2	3	2	3	1	..	..	..	..	..	..
1½ in.	13	23	19	18	21	19	2	5	7	6	7	2
1 in.	40	54	49	50	48	49	24	40	34	34	34	33
¾ in.	57	69	65	64	61	64	44	58	53	55	52	53
½ in.	80	87	85	83	81	84	66	77	74	73	70	73
¼ in.	99	99	100	99	99	99	95	97	97	96	95	96
SLAG												
1½ in.	6	7	6	5	5	7	1	2	1	1	1	2
1 in.	37	38	32	36	34	40	28	26	25	27	25	32
¾ in.	59	58	53	55	53	61	48	46	42	45	42	50
½ in.	82	80	76	80	76	83	74	71	66	71	66	74
¼ in.	99	98	99	99	98	99	97	95	95	96	94	97
GNEISS												
3 in.	1	6	5	3	2	5	..	..	..	..	..	..
2½ in.	10	11	9	12	11	17	0	4	3	2	0	1
2 in.	29	28	27	27	29	31	9	12	9	14	9	13
1½ in.	48	45	44	47	46	53	33	34	30	32	32	38
1 in.	68	66	68	68	70	76	56	55	54	56	56	64
¾ in.	86	84	86	86	86	90	76	75	75	75	76	83
½ in.	97	96	97	97	97	98	92	91	91	92	92	95
¼ in.	99	99	99	99	99	99	99	99	98	99	99	99

TABLE IV.—AVERAGE GRADING OF SAMPLES A AND B.

Screen	Total Retained on Each Screen, per cent											
	Round Openings						Square Openings					
	Portland Cement Assn.		Standard Slag Co.		Bureau of Public Roads		Portland Cement Assn.		Standard Slag Co.		Bureau of Public Roads	
	A	B	A	B	A	B	A	B	A	B	A	B
GRAVEL												
2½ in.	0	0	0	0	0	0	..	..	..	..	..	..
2 in.	2	1	2	2	2	4	0	0	0	0	0	0
1½ in.	13	15	18	17	17	19	6	6	8	7	8	9
1 in.	44	45	53	53	47	50	33	34	39	38	34	37
¾ in.	60	61	66	65	65	67	53	56	61	61	56	59
½ in.	80	80	82	83	82	83	70	75	74	75	73	75
¼ in.	99	99	99	99	99	99	95	95	95	96	95	96
LIMESTONE												
2½ in.	1	3	2	3	2	2	0	0	0	0	0	0
2 in.	9	11	7	9	14	12	2	3	2	3	3	3
1½ in.	18	19	23	24	27	26	11	14	15	17	18	17
1 in.	30	30	35	36	37	36	23	23	26	28	30	29
¾ in.	50	50	57	59	59	57	37	38	43	46	42	41
½ in.	80	79	84	87	82	80	65	64	70	73	68	68
¼ in.	98	98	98	98	99	98	94	95	96	96	94	94
TRAP												
2 in.	0	0	1	3	2	2	0	0	0	0	0	0
1½ in.	11	12	17	19	18	19	2	4	7	6	5	5
1 in.	37	38	46	48	48	49	26	28	32	33	33	34
¾ in.	53	53	61	63	64	63	42	43	51	53	52	53
½ in.	80	79	84	87	84	83	64	63	73	74	72	72
¼ in.	99	98	99	99	99	99	95	94	96	97	96	96
SLAG												
2 in.	0	0	0	0	0	0	..	..	0	0	0	0
1½ in.	4	4	7	7	6	6	0	0	1	1	1	1
1 in.	30	30	35	32	36	37	23	22	27	24	26	28
¾ in.	53	51	55	53	57	56	41	39	45	43	45	46
½ in.	77	75	82	80	79	80	68	65	72	71	70	70
¼ in.	99	98	99	99	99	99	94	94	97	96	96	96
GNEISS												
3 in.	2	2	2	2	4	3	..	..	0	1	0	0
2½ in.	15	10	13	12	10	13	0	0	..	..	2	1
2 in.	30	24	27	29	28	29	11	10	13	13	10	12
1½ in.	46	42	47	47	46	49	36	30	38	36	32	34
1 in.	70	67	69	70	67	71	58	56	55	57	55	59
¾ in.	86	84	85	87	85	87	78	76	77	78	75	78
½ in.	96	96	97	97	97	97	92	91	92	93	91	93
¼ in.	99	99	99	99	99	99	98	98	98	99	99	99

TABLE V.—AVERAGE GRADINGS OF SAMPLES USED IN COMPARATIVE MECHANICAL ANALYSES OF COARSE AGGREGATES.

Screen	Total Retained on Each Screen, per cent											
	Average Grading of Entire Sample						Average of All Laboratories					
	Round Opening			Square Opening			Round Opening			Square Opening		
	Portland Cement Assn.	Standard Slag Co.	Bureau of Public Roads	Portland Cement Assn.	Standard Slag Co.	Bureau of Public Roads	A	B	Total	A	B	Total
GRAVEL												
2½ in.	0	0	0	..	..	..	0	0	0	..	..	..
2 in.	2	2	3	0	0	0	2	2	2	0	0	0
1½ in.	14	18	18	6	7	8	16	17	17	7	7	7
1 in.	45	53	48	34	39	35	48	49	49	34	36	36
¾ in.	60	66	66	54	61	58	64	65	64	57	58	58
½ in.	80	83	82	72	74	74	81	82	82	72	75	73
¼ in.	99	99	99	95	95	96	99	99	99	95	96	95
LIMESTONE												
2½ in.	2	2	2	0	0	0	2	3	2	0	0	0
2 in.	10	8	13	2	3	3	10	11	10	2	3	3
1½ in.	19	23	27	13	16	18	23	23	23	15	16	16
1 in.	30	35	37	23	27	30	34	34	34	26	27	27
¾ in.	50	58	58	38	44	42	55	55	55	41	42	41
½ in.	80	85	81	64	71	68	82	82	82	68	68	68
¼ in.	98	98	99	94	96	94	98	98	98	95	95	95
TRAP												
2 in.	0	2	2	0	0	0	1	2	1	0	0	0
1½ in.	12	18	17	3	6	5	16	17	16	5	5	5
1 in.	38	47	48	27	32	33	44	45	44	30	32	31
¾ in.	53	62	63	43	52	52	59	60	59	48	50	49
½ in.	79	86	83	64	74	72	83	83	83	70	70	70
¼ in.	98	99	99	94	97	96	99	99	99	96	96	96
SLAG												
2 in.	0	0	0	..	0	0	0	0	0	0	0	0
1½ in.	4	7	6	0	1	1	6	6	6	1	1	1
1 in.	30	33	36	23	25	27	34	33	33	25	25	25
¾ in.	52	55	56	40	44	46	55	53	54	44	43	43
½ in.	76	81	80	66	71	70	79	78	79	70	69	69
¼ in.	98	99	99	94	96	96	99	99	99	96	95	95
GNEISS												
3 in.	2	2	4	..	..	..	3	2	3	0	0	0
2½ in.	12	12	12	..	0	2	13	12	12	1	0	1
2 in.	27	28	28	11	13	11	28	27	28	11	12	12
1½ in.	44	47	47	32	37	33	46	46	46	35	33	34
1 in.	68	70	69	57	56	57	69	69	69	57	57	57
¾ in.	85	86	86	77	77	77	85	86	86	77	77	77
½ in.	96	97	97	91	93	92	97	97	97	92	92	92
¼ in.	99	99	99	98	99	99	99	99	99	98	99	99

TABLE VI.—MAXIMUM VARIATIONS IN PERCENTAGE RETAINED BETWEEN THREE TESTS ON EACH SAMPLE AND FOR EACH LABORATORY.

Screen	Round Openings						Square Openings					
	Sample A			Sample B			Sample A			Sample B		
	Portland Cement Assn.	Standard Slag Co.	Bureau of Public Roads	Portland Cement Assn.	Standard Slag Co.	Bureau of Public Roads	Portland Cement Assn.	Standard Slag Co.	Bureau of Public Roads	Portland Cement Assn.	Standard Slag Co.	Bureau of Public Roads
GRAVEL												
2 in.	3	1	2	3	2	3	..	..	..	..	..	..
1½ in.	2	2	6	4	2	7	3	3	2	3	4	2
1 in.	13	4	5	6	5	6	12	5	6	7	6	7
¾ in.	12	5	7	5	1	5	15	5	7	6	2	6
½ in.	7	6	3	3	2	4	8	6	5	9	4	4
¼ in.	1	0	0	1	0	0	4	3	0	2	1	2
LIMESTONE												
2½ in.	2	1	3	1	3	1	..	..	..	..	..	..
2 in.	5	3	3	3	5	2	4	3	5	5	4	3
1½ in.	5	10	3	6	2	2	2	10	2	5	5	4
1 in.	10	13	1	7	5	4	6	9	2	8	5	8
¾ in.	12	8	3	10	6	3	11	12	2	10	8	2
½ in.	17	6	3	5	1	2	18	7	3	8	3	3
¼ in.	2	1	0	2	1	1	5	1	1	4	0	2
TRAP												
2 in.	..	2	2	..	1	2	..	..	..	..	..	..
1½ in.	5	1	10	1	5	3	2	1	5	2	3	5
1 in.	4	7	14	5	2	2	5	8	16	4	1	1
¾ in.	5	6	12	4	2	3	5	7	14	3	4	3
½ in.	4	6	7	3	1	3	3	11	11	2	1	3
¼ in.	1	0	1	1	0	0	3	3	2	1	0	1
SLAG												
1½ in.	2	2	1	4	4	2	1	0	1	..	1	1
1 in.	6	5	6	9	10	6	10	4	3	8	7	7
¾ in.	5	7	6	8	9	8	7	6	6	11	6	8
½ in.	6	3	6	4	6	7	8	7	8	6	5	8
¼ in.	1	0	1	1	0	1	1	2	2	1	0	3
GNEISS												
3 in.	3	4	5	4	2	3	..	..	..	..	..	..
2½ in.	6	8	2	6	10	6	..	..	4	..	..	2
2 in.	5	13	2	9	15	4	9	12	3	7	12	5
1½ in.	6	12	4	13	13	7	7	9	4	9	15	6
1 in.	2	2	2	16	15	8	5	10	2	15	15	8
¾ in.	1	5	2	12	8	4	2	6	1	15	10	8
½ in.	2	3	1	4	2	1	3	3	1	8	4	3
¼ in.	1	1	0	2	0	0	2	1	1	2	1	0

TABLE VII.—VARIATION IN AVERAGE PERCENTAGE RETAINED BETWEEN SAMPLES A AND B FOR EACH LABORATORY.

Screen	Round Openings			Square Openings		
	Portland Cement Assn.	Standard Slag Co.	Bureau of Public Roads	Portland Cement Assn.	Standard Slag Co.	Bureau of Public Roads
			GRAVEL			
2 in.	1	0	2	..	..	..
1½ in.	2	1	2	0	1	1
1 in.	1	0	3	1	1	3
¾ in.	1	1	2	3	0	3
½ in.	0	1	1	5	1	2
¼ in.	0	0	0	0	1	1
			LIMESTONE			
2½ in.	2	1	0	..	..	..
2 in.	2	2	2	1	1	0
1½ in.	1	1	1	3	2	1
1 in.	0	1	1	0	2	1
¾ in.	0	2	2	1	3	1
½ in.	1	3	2	1	3	0
¼ in.	0	0	1	1	0	0
			TRAP			
2 in.	..	2	0	..	..	..
1½ in.	1	2	1	2	1	0
1 in.	1	2	1	3	1	1
¾ in.	0	2	1	1	2	1
½ in.	1	3	1	1	1	0
¼ in.	1	0	0	1	1	0
			SLAG			
2 in.	..	..	..	..	..	..
1½ in.	0	0	0	0	0	0
1 in.	0	3	1	1	3	2
¾ in.	2	2	1	2	2	1
½ in.	2	2	1	3	1	0
¼ in.	1	0	0	0	1	0
			GNEISS			
3 in.	0	0	1	..	1	..
2½ in.	5	1	3	..	..	1
2 in.	6	2	1	1	0	2
1½ in.	4	0	3	6	2	2
1 in.	3	1	4	2	2	4
¾ in.	2	2	2	2	1	3
½ in.	0	0	0	1	1	2
¼ in.	0	0	0	0	1	0

TABLE VIII.—DIFFERENCE BETWEEN PERCENTAGE RETAINED ON ROUND AND SQUARE OPENINGS FOR EACH LABORATORY AND FOR AVERAGE OF ALL LABORATORIES.

Screen	Portland Cement Assn.	Standard Slag Co.	Bureau of Public Roads	Average A	Average B	General Average
			GRAVEL			
2 in.	2	2	3	2	2	2
1½ in.	8	11	10	9	10	10
1 in.	11	14	13	14	13	13
¾ in.	6	5	8	7	7	6
½ in.	8	9	8	9	7	9
¼ in.	4	4	3	4	3	4
			LIMESTONE			
2½ in.	2	2	2	2	3	2
2 in.	8	5	10	8	8	7
1½ in.	6	7	9	8	7	7
1 in.	7	8	7	8	7	7
¾ in.	12	14	16	14	13	14
½ in.	16	14	13	14	14	14
¼ in.	4	2	5	3	3	3
			TRAP			
2 in.	0	2	2	1	2	1
1½ in.	9	12	12	11	12	11
1 in.	11	15	15	14	13	13
¾ in.	10	10	11	11	10	10
½ in.	15	12	11	13	13	13
¼ in.	4	2	3	3	3	3
			SLAG			
2 in.	0	0	0	0	0	0
1½ in.	4	6	5	5	5	5
1 in.	7	8	9	9	8	8
¾ in.	12	11	10	11	10	10
½ in.	10	10	10	9	9	10
¼ in.	4	3	3	3	4	4
			GNEISS			
3 in.	2	2	4	3	2	3
2½ in.	12	12	10	12	12	11
2 in.	16	15	17	17	15	16
1½ in.	12	10	14	11	13	12
1 in.	11	14	12	12	12	12
¾ in.	8	9	9	8	9	9
½ in.	5	4	5	5	5	5
¼ in.	1	0	0	1	0	0

test sample drawn from the pile. Three samples were analyzed for each material in this manner, using both types of screens. The results of these three determinations are given in the tables under the heading "Sample *A*."

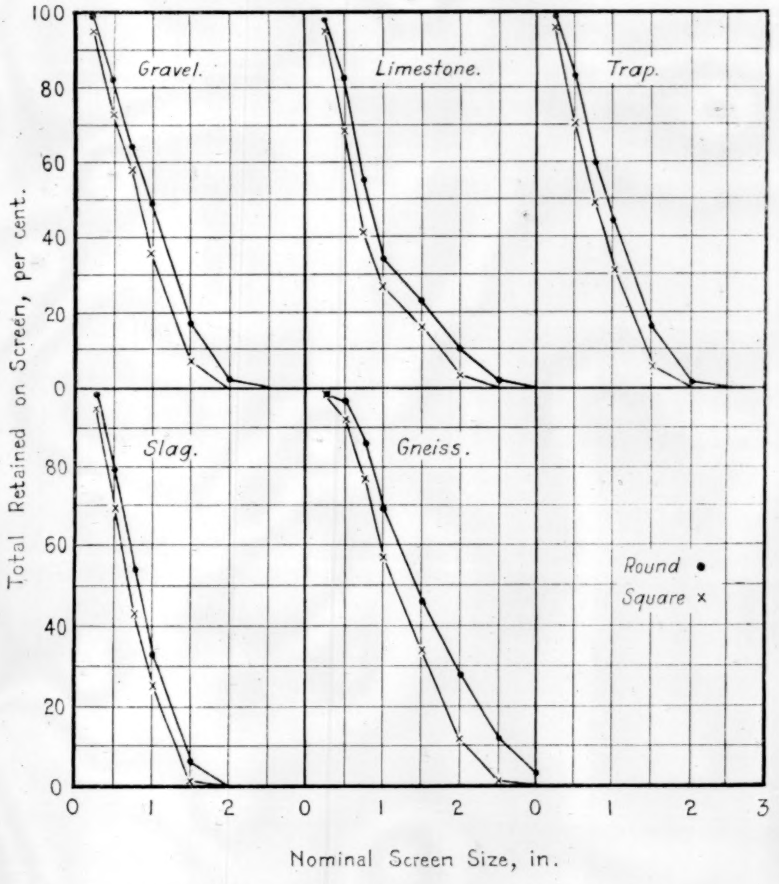

FIG. 1.—Results of Screen Test Showing Average Grading of Samples.

The above three test samples were then recombined with the residue, the whole thoroughly mixed and the entire procedure repeated. These tests are given in the tables under the heading "Sample *B*." The original samples were collected and distributed by the Bureau of Public Roads and the material sent to each laboratory was, for each type, as nearly identical as possible.

These data were discussed thoroughly by the committee at its meeting on March 22 and a summary of the discussion follows:

Reference to Tables I to III, inclusive, as well as to Table VI, will show that there is quite an appreciable range in the sieve analysis between individual test samples taken from a pile. Furthermore, that this variation seems to be about as marked for one type of opening as for the other, and was apparent in the work of all three laboratories. These data indicate that a considerable error was introduced through an attempt to determine the sieve analysis of an aggregate

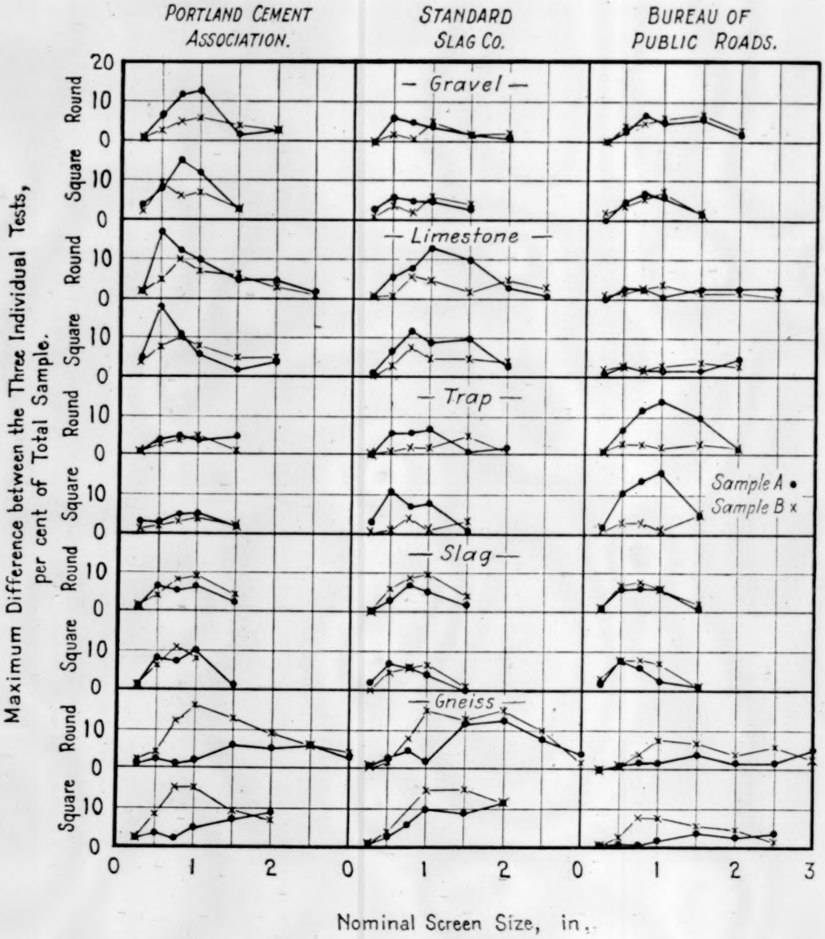

FIG. 2.—Results of Screen Test Showing Maximum Differences Between Three Individual Tests.

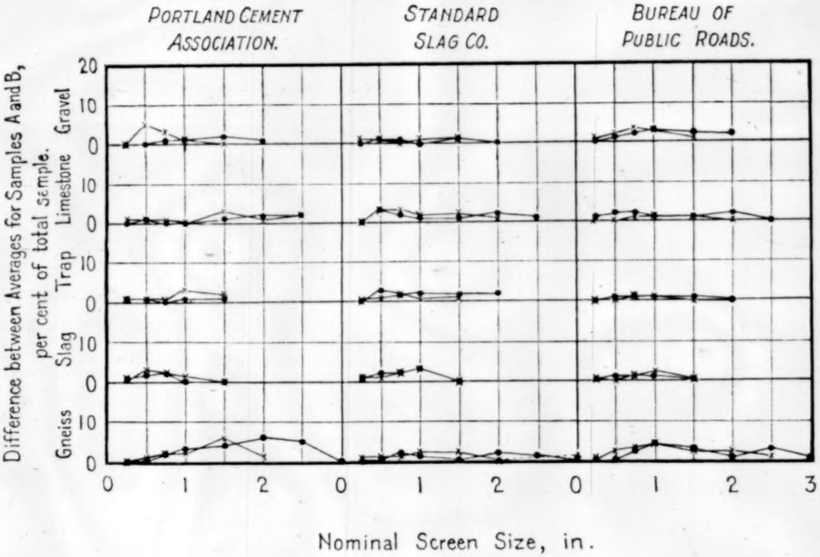

FIG. 3.—Results of Screen Test Showing Differences Between Averages for Samples *A* and *B*.

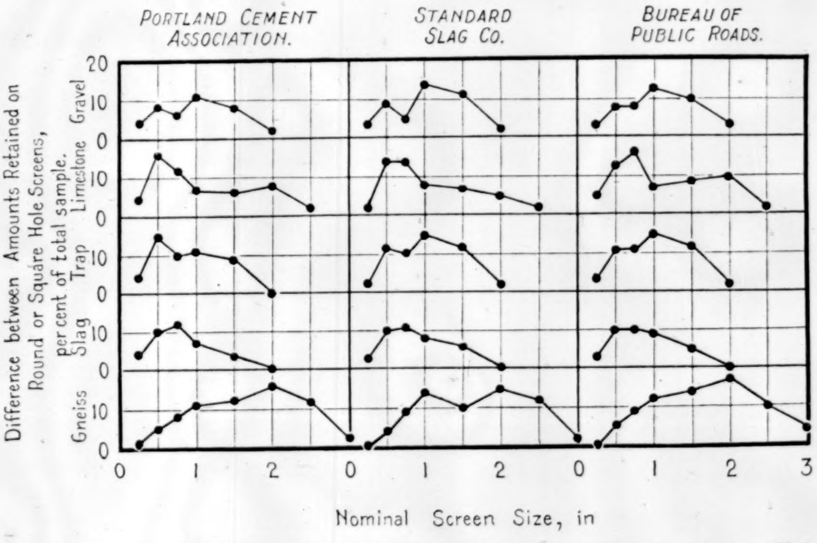

FIG. 4.—Showing Differences Between Amounts Retained on Round or Square-Hole Screens.

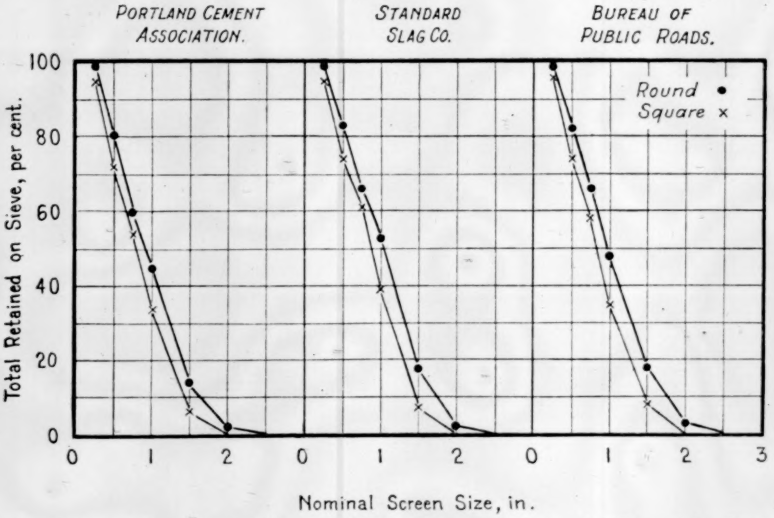

FIG. 5.—Results of Screen Test Showing Average Grading for Gravel for Each Laboratory.

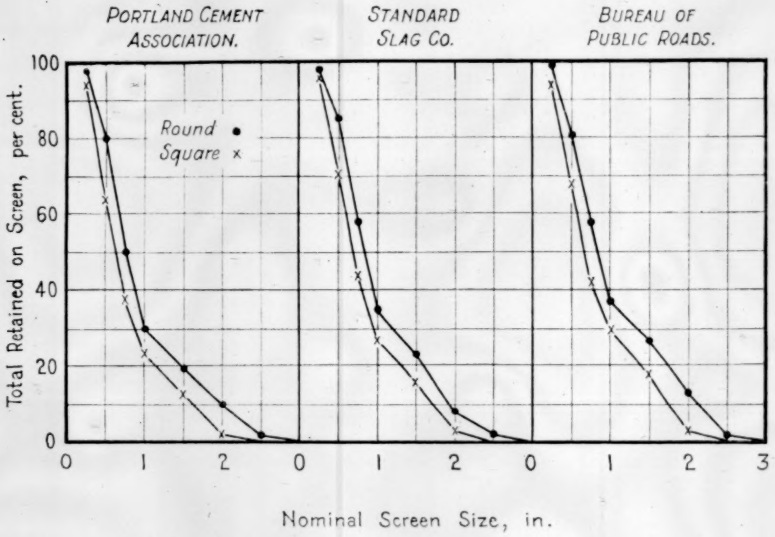

FIG. 6.—Results of Screen Test Showing Average Grading for Limestone for Each Laboratory.

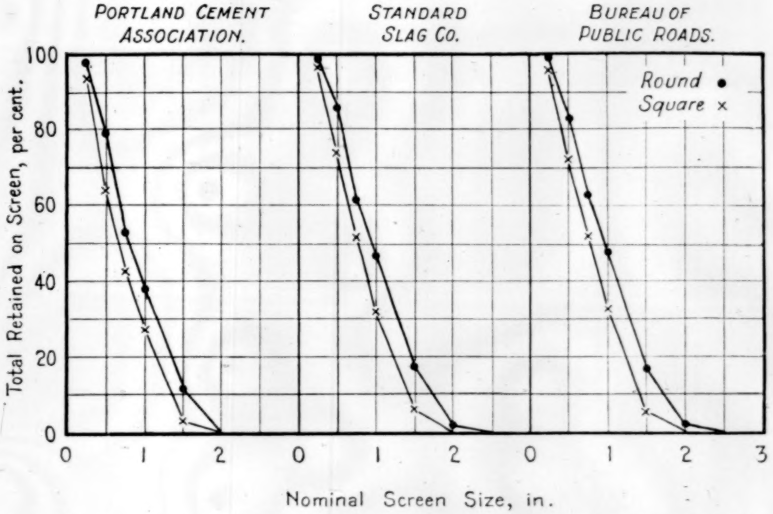

FIG. 7.—Results of Screen Test Showing Average Grading for Trap for Each Laboratory.

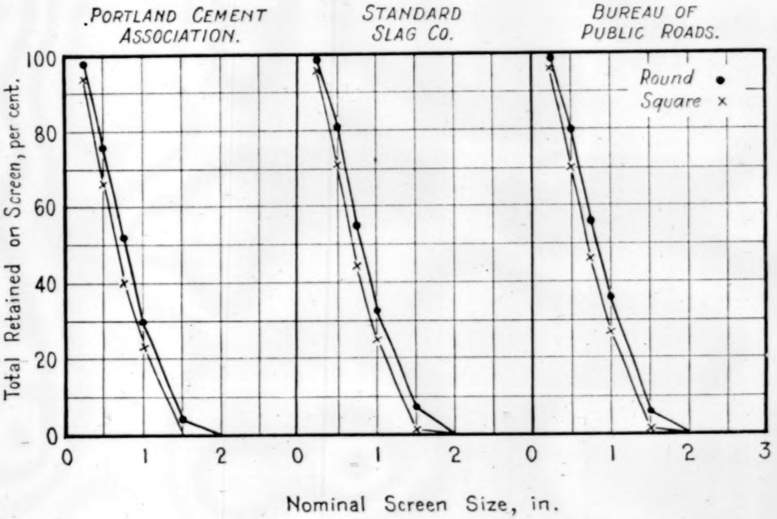

FIG. 8.—Results of Screen Test Showing Average Grading for Slag for Each Laboratory.

stock pile by the analysis of a small sample obtained by the standard method of quartering.

In Table IV the average grading for both samples *A* and *B* and for each laboratory and each material is given, whereas, in Table VII the variation in average percentage between samples *A* and *B* for each laboratory is indicated. These data indicate that the difference between the average results as obtained on samples *A* and *B* were about the same for both types of opening, showing that from the standpoint of concordance of results there was very little to choose between the two types. Furthermore, it will be noted that the variations between the average results for sample *A* and sample *B* for either type of screen are considerably less than the variations between individual test samples (see Table VI).

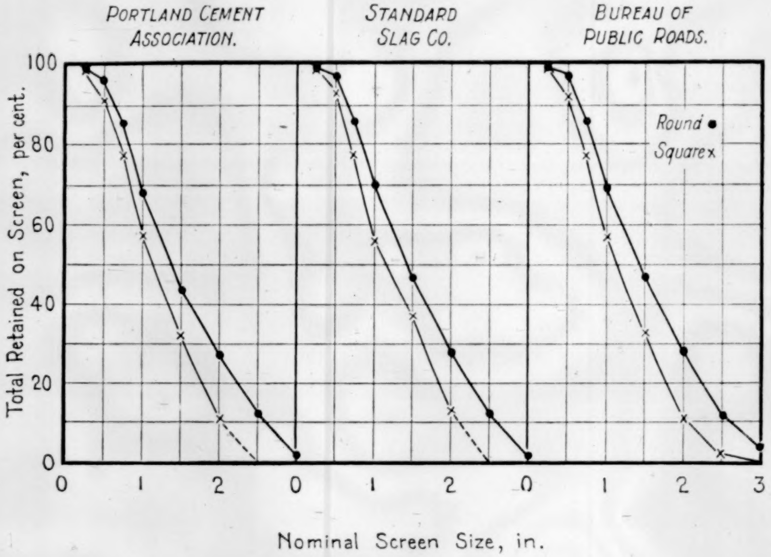

FIG. 9.—Results of Screen Test Showing Average Grading for Gneiss for Each Laboratory.

The difference between the percentage retained on the round and on the square opening for each laboratory and for the average of all laboratories is given in Table VIII. These variations are likewise plotted for each of the five materials in Fig. 1 and for each of the three laboratories on the five materials in Figs. 5, 6, 7, 8 and 9. Reference to these charts indicates that although the three laboratories check very closely for each of the five materials, the sieve analysis curves were not of similar shape and also that the difference between the total amount retained on the round-hole screen which would pass the square-mesh sieve of the same size differs considerably for different materials. This would indicate that the influence of shape of fragment would render it difficult to prepare a table of conversion factors which would be of general application.

As the result of the above-described series of tests, the committee is of the opinion: (1) that neither type of testing screen has any advantage over the other type from the standpoint of concordance of results secured on repeated tests on the same sample, and (2) that it will be impracticable to establish a table of conversion factors for converting results obtained by one type of screen into results for the other type.

The committee, after thoroughly canvassing the present situation as regards the use of testing sieves and screens for the determination of size of aggregates, recommends that the round-hole screen be considered as a standard type for test purposes in the measurement of the size of such materials as crushed stone, gravel, blast furnace slag, etc., used in road construction and in concrete, with the thought that this recommendation be put into effect by the Society through the revision by the standing committees concerned of each of the standards affected, the revision to become effective by January 1, 1930.

This report has been submitted to letter ballot of the committee, which consists of 15 members, of whom 8 have voted affirmatively, 5 negatively, and 2 have refrained from voting.

Respectfully submitted on behalf of the Section on Coarse Screens,

F. H. JACKSON,
Chairman.

REPORT OF SECTION ON SUB-SIEVE SIZES

The Section on Sub-Sieve Sizes, of Technical Committee IV on Size and Shape, has a membership of thirty, representing twenty-six laboratories. Of this number, however, only eleven laboratories take an active part in the work of the section.

The first meeting during the past year was held in theo ffices of the New Jersey Zinc Co. in New York City on July 5, 1927, with eleven members in attendance. The second meeting was held at Columbia University on March 24, 1928, with twelve members present. Both meetings were devoted largely to the presentation of the needs of the various industries represented, although some very valuable work has been done and the data resulting from this work are here presented.

At the beginning of the year a series of nine samples, representing a particle size range from through a 75-micron sieve opening (Sieve No. 200) down to particles below the resolving power of the ordinary compound microscope, were prepared and submitted to various members of the committee for particle size determination. These samples were three grades of zinc oxide, zinc dust, red lead, cement rock, coal dust, marble dust and anhydrous gypsum.

As reports on these tests were prepared, it became quite obvious that methods of reporting and representing the results obtained were of first consideration, as only two reports of the eight submitted had succeeded in giving results that were directly comparable.

There were in general three types of representation used by various members of the committee: Type 1, those who wanted particle size measurements by a direct method, so as to be able to express all the various average diameters in microns; Type 2, those interested in expressing one particular average diameter using an indirect method calibrated by the direct method; and Type 3, those using indirect methods calibrated by some law or formula to give one particular average diameter, or whose work permits the expression of results in some unit other than microns, such as percentage class size, where class size is defined by the velocity of a stream of air or liquid used to separate a portion of the sample.

The nature of the reports submitted to date is shown in Table I, but the results themselves will not be tabulated at this time. No effort will be made at this time to correlate the results given by indirect methods owing to the lack of uniformity in the expression

TABLE I.—SUMMARY OF REPORTS SHOWING METHOD USED AND UNITS USED TO EXPRESS RESULTS IN PARTICLE SIZE DETERMINATION.

	Zinc Oxide "A"	Zinc Oxide "B"	Zinc Oxide "C"	Zinc Dust	Red Lead	Cement Rock	Coal Dust	Marble Dust	Anhydrous Gypsum
Drinker, Harvard University	Optical method, (intensity of Tyndall Beam).	Optical method, (intensity of Tyndall Beam).	Optical method, (intensity of Tyndall Beam).	Microscopic method, absolute units.				Separation by settling, optical method, (intensity of Tyndall beam).	
New Jersey Zinc Co.	Optical method, absolute units.	Microscopic Method, absolute units.	Microscopic method, absolute units.	Microscopic method, absolute units.	Separation by settling, microscopic method, absolute units.	Separation by settling, microscopic method, absolute units.	Separation by settling, microscopic method, absolute units.	Separation by settling, microscopic method, absolute units.	Separation by settling, microscopic method, absolute units.
B. F. Goodrich Co.	Microscopic method, absolute units.								
Eagle-Picher Lead Co.		Sedimentation, absolute units.	Sedimentation, absolute units.	Sedimentation, absolute units.	Sedimentation, absolute units.			Sedimentation, absolute units.	
National Lead Co.		Microscopic method, absolute units.	Microscopic method, absolute units.	Microscopic method, absolute units.	Thompson classifier, per cent class size. Microscopic method, absolute units.	Thompson classifier, per cent class size.		Thompson classifier, per cent class size.	Thompson classifier, per cent class size.
Lehigh Portland Cement Co.				Air classifier, per cent class size.	Air classifier, per cent class size.	Air classifier, per cent class size.	Air classifier, per cent class size.	Air classifier, per cent class size.	Air classifier, per cent class size.
Celite Co.			Sedimentation, absolute units.	Microscopic method, absolute units. Sedimentation, absolute units.					

of results, and they will be recalculated to agree with the definitions and methods of expressions adopted at the last meeting. This nomenclature is given later in this report. Some comparison of results obtained by the direct method of measurement can be made, however.

The particle size of five of the nine samples was determined by the direct method by more than one investigator and in every case results checked within 10 per cent. For example, four investigators using different dispersions, different magnifications and different methods of viewing and measuring, in the case of the zinc dust sample checked each other within 10 per cent.

The committee feels that these results establish pretty thoroughly the direct method of measuring particle size as the foundation on which the future work of the committee must be based.

It will be noticed that the committee has devoted its attentions entirely to "size" of fine-particles in this report and neglected "shape." Several members of the committee have done some work along this line, but there are as yet no definite results to report. It is hoped that the activities of the committee for the coming year will include a program on this very important phase of the work.

The value of the direct measurement cannot be over-emphasized for, as pointed out by Henry Green, in the Institution of the Rubber Industry Transactions: "The value of a direct method for the measurement of particle size is due to the fact that it gives a particle distribution curve, and that such a method does not always impose the necessity for assuming cubical or spherical particles. From the particle distribution curve all the necessary information is derived that enables the investigator to calculate the particular average diameter that is required for this work."

The committee, while agreeing that the direct measurement is fundamentally essential if results are to be expressed in terms of micron size of the ultimate particle, is anxious to advance and develop new methods of the nature of Type 2 methods, mentioned above. Methods of direct measurement are long and tedious and too time consuming to be practicable for routine work. Some of the members of the committee have been working along lines that will offer a rapid and yet accurate method for determining some one property of a material that is governed by particle size alone. Methods of this type may be calibrated by the direct method using the average diameter most nearly representing the property being measured. Great care must be exercised in this work to establish a procedure so that any variation in the property measured is a function of particle size alone. Methods being used by members of the committee are mainly optical ones, such as the measurement of the intensity of the Tyndall beam, the scopometer of Exton and Wells and the opacity method of Stutz and Pfund.

Type 3 methods, involving all the indirect methods, the sedimentation method, elutriation and various other separation methods, may be calibrated by the direct method, but more often are based on Stokes' law. Results obtained by these methods offer the individual industry employing them, results which can be interpreted as the needs dictate. The most common method is to express results in percentage class size. It should be clearly understood that there are several other major variables entering into these tests and reliable conclusions regarding particle size can only be obtained when extreme care is taken to keep other conditions of the test constant.

DEFINITION AND DISCUSSION OF TERMS AND SYMBOLS

The following definitions have been prepared to guide the committee in its work.

1. *Dispersion.*—In statistical work dispersion is measured by the standard deviation. In microscopy it refers to the degree of distribution of the individual particles. Both uses of the word seem too generally accepted to warrant a change in either.

2. *Individual Particle.*—The term individual particle refers to those minute units of matter (of which the material is composed) whose size and shape depend only on the force of cohesion. Such particles cannot be subdivided without separating like molecules that are within the range of the cohesive attraction of one another.[1]

3. *Ultimate Working Unit.*—An ultimate working unit may be an individual particle, or it may be any group of individual particles that are so firmly held together by forces of adhesion that they remain intact as a group throughout the duration of their application.[1]

4. *Aggregate.*—Any group of two or more attached particles is an aggregate. There are three forms of aggregates, the flocculate being the most important.

5. *Flocculate.*—Flocculation occurs only where particles have been incorporated in a liquid or plastic medium. A flocculate is a group of particles held together by a force, apparently arising from surface tension, at the interface. This force of flocculation is relatively weak, consequently flocculates do not function as large individual particles, and cannot be classified under ultimate working units. Under slight continuously applied force flocculates are constantly breaking down and reforming.[1]

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[1] H. Green, *Journal Industrial Hygiene*, 1925, Vol. 7, p. 155.

Apparent flocculates as found in gas—or air-floated particles—show a somewhat similar type of aggregation. Usually the force of attraction between the particles is relatively weak and the particles can readily be dispersed in suitable media. For practical purposes, the more inclusive term, aggregate, is preferable to flocculate for gas- or air-floated particles.

6. *Average Diameter.*—An average diameter is the diameter of a hypothetical particle which, in some particular way, represents the total mass of particles.

7. *Non-uniformity.*—A non-uniform particulate substance is one in which the constituent particles differ from one another in diameters.

Results will be expressed using one or more of the following average diameters:

AVERAGE DIAMETER		FORMULA
d_1	to be used as arithmetical mean	$d_1 = \frac{\Sigma\, nd}{\Sigma\, n}$
d_3	to be used to determine S when ρ is known	$d_3 = \frac{\Sigma\, nd^3}{\Sigma\, nd^2}$
d_4	to be used to determine volume or weight distribution	$d_4 = \frac{\Sigma\, nd^4}{\Sigma\, nd^3}$
D	to be used to determine N when ρ is known	$D = \sqrt[3]{\frac{\Sigma\, nd^3}{\Sigma\, n}}$
Δ	to be used to determine S when N is known	$\Delta = \sqrt{\frac{\Sigma\, nd^2}{\Sigma\, n}}$
M_g	to be used as geometric mean or median	$\log M_g = \frac{\Sigma\, n \log d}{\Sigma\, n}$

SYMBOLS

S_m = specific surface in square meters per gram.
S_v = specific surface in square meters per cubic centimeter.
N_m = number of particles per gram.
N_v = number of particles per cubic centimeter.
Σn = number of particles in any given mass.
ρ = density of the material.
δ = arithmetic standard deviation.
δ_g = geometric standard deviation.
$P.E.$ = probable error.

Respectfully submitted on behalf of the Section on Sub-Sieve Sizes,

J. P. HUBBELL,
Chairman.

REPORT OF TECHNICAL COMMITTEE V ON METHODS FOR DENSITY

A number of standards or tentative standards of the Society involve the determination of some form of specific gravity or unit weight and the use of density tests is common to a great variety of materials covered in the Society standards. These materials upon which density tests are made include the following:

Fine Aggregate for Concrete
Coarse Aggregate for Concrete
Lacquer Solvents and Diluents
Boiled Linseed Oil
Pigments
Raw Tung Oil
Soft Tar Pitches, Road Oils, Road Tars, Asphalt Cement
Solid Tars and Asphalt Cements
Electrical Porcelain
Soya Bean Oil
Timber
Gas Oils
Portland Cement
Refractory Materials
Concrete Materials
Raw Linseed Oil
Linseed Oil
Creosote Oil
Red Lead
Perilla Oil
Yellow and Orange Pigments
Titanium Pigments
Sand and Screenings
Lump Coke

It will be seen that the materials listed above are of very wide variety and involve fine powders such as paint pigment, portland cement; fine particles in bulk such as sand and stone or slag screenings; coarse fragments in bulk such as coarse aggregate in concrete; solids such as timber and electrical porcelain; and various kinds of liquids ranging from those having low viscosity to those merging into the semi-solids. Plainly, various kinds of unit weight or specific gravity determinations might well be necessary for the testing of materials varying so widely in character. Thus, in the case of the powders it is easily conceivable that we might be interested commercially in the specific gravity of the material either in its solid form or in bulk form. The same is true of the solids composed of coarse fragments. In the case of the liquids we are generally interested in the unit weight of a given volume of the liquid when it is at a given temperature. The very fact that the various liquids covered in the standards vary so widely in their viscosity, points to the possible necessity for variations in the method of making specific gravity determinations.

Commercially, the specific gravity of a material may have very great significance and importance. Powders such as hydrated lime, portland cement, and paint pigments weigh variable amounts depending upon their state of compaction. The importance of a standard method of making unit weight determinations on powdered materials thus becomes quite apparent. It is also not difficult to visualize the possibility that the solid volumes occupied by powdered materials may really have more significance than their weight in bulk form, and, therefore, the specific gravity determination of such materials may become of increasing importance. A unit weight determination in some cases is used as a control test for the quality of a material, as is now the case with blast-furnace slag.

The whole subject of density and unit weight, therefore, merits careful consideration in its application to standard specifications and standard methods of testing. The committee's function is to review the field of density and unit weight determinations:

1. To define the fundamental principles upon which specific gravity, density or unit weight determinations should be based.

2. To consider the application of these general principles to our present A.S.T.M. standards to determine:

(*a*) If the method used is correctly and completely applied;

(*b*) If the methods are as uniform as possible in their application to the various materials; and

(*c*) If the best method has been used for a particular purpose.

As a starting point the committee has reviewed the standard definitions of the Society for the terms: absolute specific gravity, specific gravity, apparent specific gravity, and bulk specific gravity appearing in the Standard Definitions of Terms Relating to Specific Gravity (E 12 - 27).[1] In discussing these definitions, it was the opinion of several of the members that when the temperature of the material and of the water are the same, the specific gravity should be expressed as follows: Specific gravity $\frac{x°\text{C.}}{x°\text{C.}}$. The same form of expression applies to the four different kinds of specific gravity.

As has been pointed out, the above terms are necessary because of the great variety of materials to which specific gravity tests are applied and also because of the commercial and practical aspects of specific gravity determinations. Correct definitions for the various forms of specific gravity are the basis upon which the work of the committee must be founded. The committee has, therefore, given thought to the above definitions. It is not prepared to accept them as fully satisfactory until it has received comments from a number of sources with which the chairman is now corresponding, including:

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 932.

the American Physical Society; the American Chemical Society; the American Society for the Promotion of Engineering Education; the Smithsonian Institution; the U. S. Bureau of Standards; the British Standards Association, and the Association of Official Agricultural Chemists.

Statement of Problem Before the Committee:

Having satisfied itself regarding the definitions for the several forms of specific gravity it is the function of the committee:

1. To outline those features which are of importance in the making of specific gravity determinations.

2. To discuss the forms of apparatus available.

3. To define the limitations of apparatus and precautions in their use.

4. To review the present and proposed standards of the Society for the purpose of:

(*a*) Determining if the fundamental requirements for specific gravity determinations are in all cases complied with.

(*b*) Determining if the right name is given to the particular kind of specific gravity described.

(*c*) Determining if the number of methods now specified may not be reduced.

The committee presents the present report as an outline of the procedure which it proposes to follow with the request that criticisms and suggestions be sent to the chairman.

Respectfully submitted on behalf of the Technical Committee on Methods of Test for Density,

A. T. GOLDBECK,
Chairman.

REPORT OF COMMITTEE E-4
ON
METALLOGRAPHY

Committee E-4 has held one meeting during the past year, at French Lick Springs, Ind., on June 23, 1927.

Sub-Committee I on Selection and Preparation of Samples, of which Mr. G. F. Comstock was temporary chairman, has a new chairman, Mr. E. H. Dix, Jr., who is reporting progress, but has no further formal report at this time.

In revising the Standard Methods of Metallographic Testing of Non-Ferrous Metals and Alloys (E 5–24) in 1927, two paragraphs were inadvertently retained, the substance of which was superseded by new material in making the revision. The committee has accordingly authorized that in the next printing of these methods these paragraphs be deleted. The paragraphs in question are the next to the last paragraph on page 772 of the 1927 Book of A.S.T.M. Standards, Part I, and the next to the last paragraph on page 773, the paragraphs reading, respectively, as follows:

> For aluminum and its alloys sodium hydroxide shows up the grain structure but is liable to cause roughening. The weaker solution is recommended for details of structure and may be further diluted.
>
> The harder constituents usually show up as polished, *e. g.*, Si, $FeAl_3$, $CuAl_2$, $NiAl_3$, and Mg_2Si. To differentiate between them the last three solutions can be used.

Sub-Committee II on Nomenclature and Definitions, Mr. Arthur Phillips, chairman, has had referred to it the preparation of a definition for "fiber in steel." This definition was requested by the committee because of considerable work being done on this subject. A tentative definition has been prepared and will be reported on at the next meeting.

Sub-Committee III on Thermal Analysis also has a new chairman, Mr. Howard Scott, succeeding Mr. W. E. Ruder, who resigned. Mr. Scott is completely reorganizing the committee and will revise the present Tentative Recommended Practice for Thermal Analysis in the light of various criticisms received.

Sub-Committee IV on Photography, Mr. H. S. Rawdon, chairman, is presenting, appended hereto, a short but interesting and instructive paper, written by Mr. H. S. George, and revised by himself and other members of E-4, on "Conical Illumination in Microscopy."

Sub-Committee VI on X-ray (Crystal) Analysis, Mr. Zay Jeffries, chairman, has a report in preparation.

The committee recommends that the present Tentative Recommended Practice for Thermal Analysis of Steel (E 14 - 25 T) which has stood for three years without revision be continued as tentative, for revisions are contemplated by Sub-Committee III.

The committee has re-elected the present officers to serve for the ensuing term of two years.

This report has been submitted to letter ballot of the committee, which consists of 49 members; 41 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

H. C. BOYNTON,
Chairman.

G. F. COMSTOCK,
Secretary.

APPENDIX

CONICAL ILLUMINATION IN MICROSCOPY

By H. S. George[1]

The illuminating pencil of light in metallographic microscopy, at least for medium and high-power work, is a solid cone-shaped beam whose axis theoretically coincides with the optic axis of the lens system. Some sections of the path may consist of parallel rays but the portion between the objective and object is a cone with its base on the objective and its apex slightly below the reflecting surface of the object when the latter is in focus. Although the full cone may be used, the central rays, those nearly normal to the reflecting surface, produce a two-fold deleterious effect and should be eliminated. Furthermore, it is better to remove certain portions of the enveloping cone, the rays of which strike the object obliquely, retaining all of the more oblique rays from one side and admitting only a few from the opposed direction. This modified beam is known as conical illumination. When obtained by an epiphragm it is called epiphragmatic illumination. A more complete description and fuller discussion of the method are given elsewhere.[2]

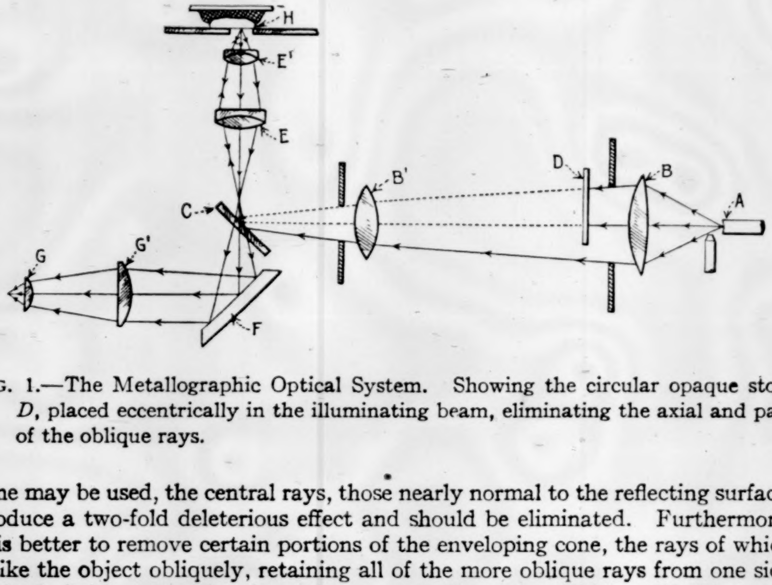

Fig. 1.—The Metallographic Optical System. Showing the circular opaque stop, *D*, placed eccentrically in the illuminating beam, eliminating the axial and part of the oblique rays.

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[1] Research Engineer, Union Carbide and Carbon Research Laboratories, Inc., Long Island City, N. Y.

[2] H. S. George, *Transactions*, Am. Soc. Steel Treating, Vol. IV, p. 140 (1923); *Transactions*, Am. Soc. Steel Treating, Vol. 5, p. 325 (1924); "Illumination in Metal Microscopy," *Journal*, Optical Soc. of America., Vol. 15, p. 295 (1927).

C. Benedicks, "Metallographic Researches," Chapter V (McGraw-Hill, 1926).

Jewell, *Journal*, Optical Soc. of America, Vol. 14, p. 159 (1927).

Figure 1 illustrates one means of producing conical illumination, by interposing a stop, *D*, at a suitable point in the beam. The essential features of such a device are the elimination of the axial rays, the elimination of any desired portion of the oblique rays, flexibility of control of the amount, and the direction and obliquity of the selected rays.

Figure 2 is a device that has proved practicable for a variety of conditions.

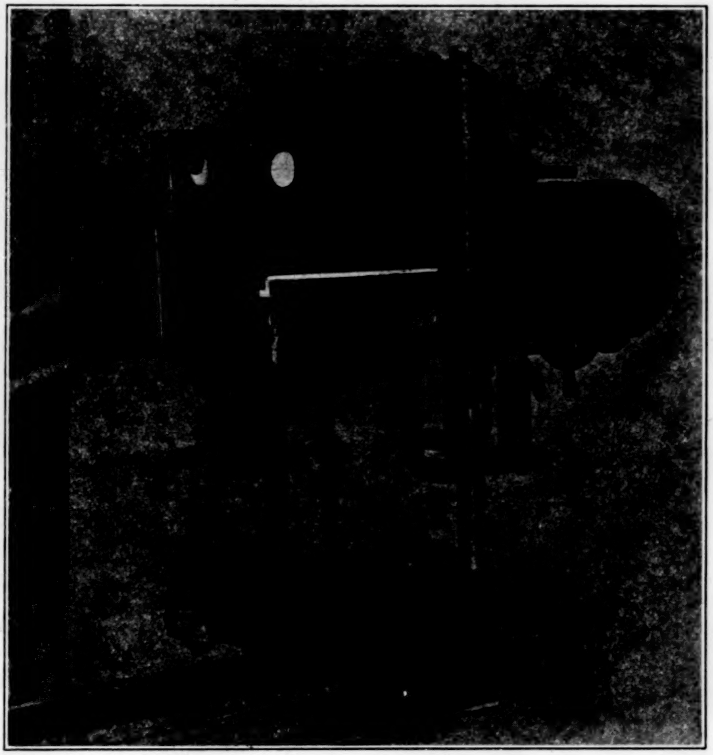

FIG. 2.—Apparatus for Producing Conical Illumination.

A mechanical stage takes the place of the usual light filter holder and contains the latter to which is affixed an opaque disk. Remote control of the position of the disk in the light beam is obtained by rods and universal joints in place of the usual knurled heads on the stage. The crescent shaped light beam can be seen on the light filter.

It consists of an opaque disk which forms an integral part of the light filter. In the illustration, the illuminant is an automatic arc adapted to a microscope of the inverted type commonly used in metallography. The filter holder, on which is mounted the opaque disk, is carried on a mechanical stage, mounted in a vertical plane, so that by means of rods attached to universal joints on the stage the opaque disk may be controlled from a distance by the observer at the microscope.

In practice the illuminator iris diaphragm is opened to its full extent and the epiphragm, an opaque disk $\frac{1}{2}$ to $\frac{3}{4}$ in. in diameter, is interposed in the beam so as to stop out the central rays and allow a beam of crescent shaped cross-section to pass to the microscope. The focal lengths of the supplementary condensers in the optical train must be such that when the disk is interposed in the beam, even concentrically, no shadow falls on the object.

It is helpful to chart the relationship between the positions of the disk,

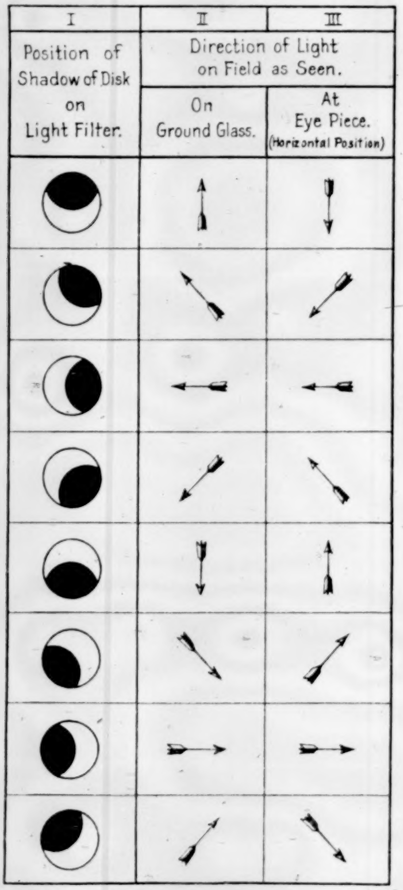
I
II
III
Position of Shadow of Disk on Light Filter.
Direction of Light on Field as Seen.
On Ground Glass.
At Eye Piece. (Horizontal Position)

FIG. 3.—Chart Showing Direction of Illumination at the Eyepiece and on the Focusing Screen for Various Positions of the Opaque Disk in the Light Beam for the Type of Microscope Described.

or the quadrant occupied by the light beam, and the direction in which the light strikes the object. Such a chart is shown in Fig. 3. This is especially needed when studying unknown features which may appear to be in relief or in *intaglio*. The appearance often presents an optical illusion, parts actually in elevation appearing depressed and *vice versa*. With the direction of lighting

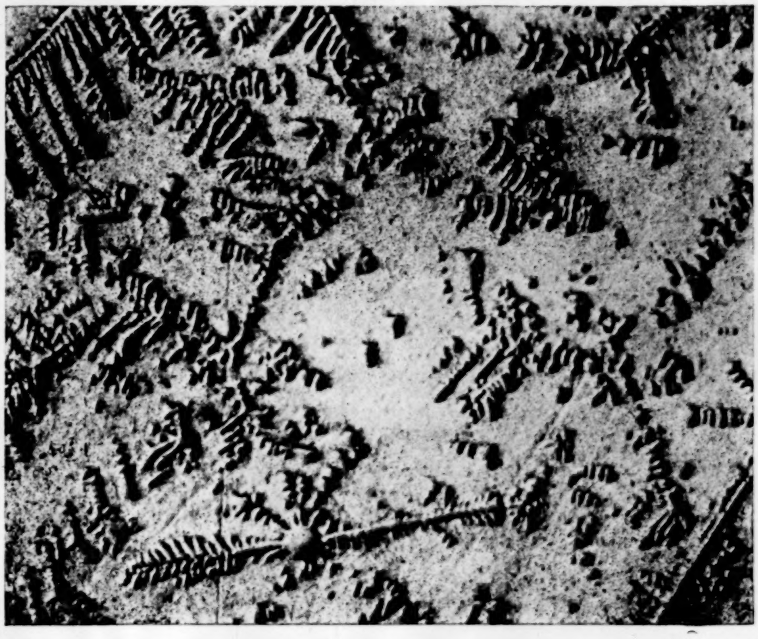

FIG. 4.—Use of Conical Illumination in Low-Power Work; Copper-Chromium Alloy (Cast), Unetched; 16-mm. Objective (× 250).

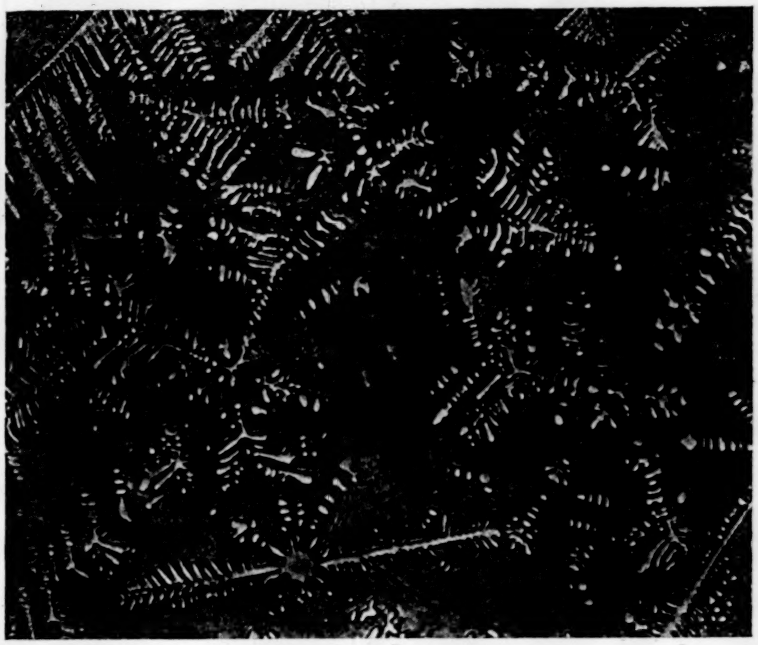

FIG. 5.—Portion of the Same Field Shown in Fig. 4, Under Axial Illumination.

known, however, the appearance may be correctly interpreted despite the illusion and it is an interesting and noteworthy fact that when the true condition is consciously evident to the observer, the illusion vanishes and the real appearance presents itself. Such a chart should be placed in a convenient position for ready reference so that the operator can, without substantially changing his own position, glance at will at the chart, the cross-section of the light beam outlined on the light filter and, also, into the microscope tube.

Although the method is apparently simple, yet for successful results, very considerable practice is required.

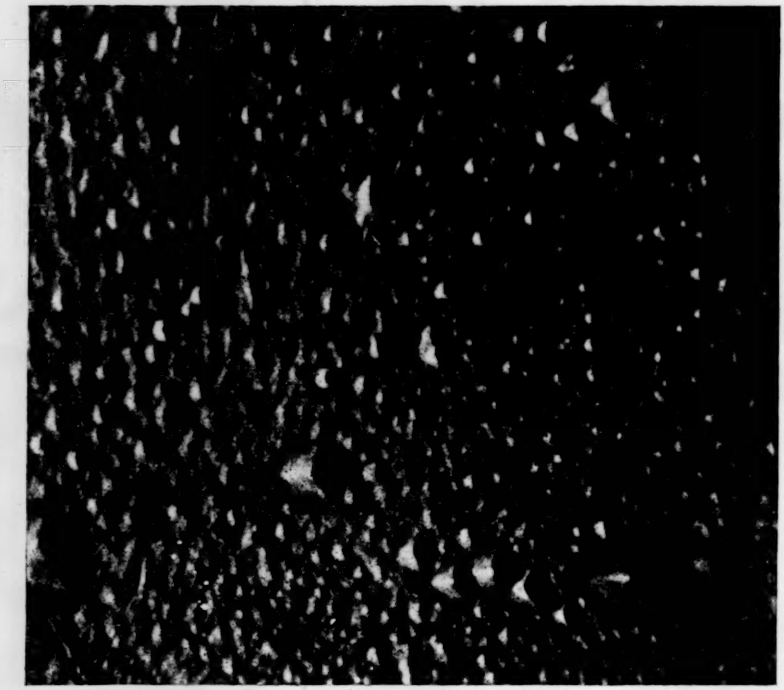

FIG. 6.—Conical Illumination as an Aid to Interpretation. So-called "etching pits" in Armco iron are shown to be really pyramids. Light is from left to right. (× 2000.)

Typical Results:

A few typical examples will indicate what may be accomplished by means of epiphragmatic lighting.

An instance of natural, realistic representation is shown in Fig. 4. This low-power photomicrograph (250 diameters) was taken of a copper-chromium alloy casting, unetched, the dendrites of excess chromium having been placed in bas-relief by suitable polishing. This naturalistic and true representation is to be contrasted with that in Fig. 5 showing the identical field but taken with ordinary axial light in the usual manner.

The aid to interpretation afforded by the exhibition of any relief possessed by metal surfaces, as, for example, in the case of grain boundaries, slip bands and so-called etching pits, is illustrated in Fig. 6. This photomicrograph taken under conical illumination of a specimen of Armco iron, at 2000 diameters, reveals the curious fact that etching "pits" are really pyramids. This has been checked many times by this method on many samples of various metals, and no instance of a real pit has so far been discovered among all the etching figures studied, although they may perhaps exist. In this instance the proof that the figures are pyramids lies in the fact that the direction of light is from left to right, lighting up the left hand slopes of the pyramids and shading the right slopes. Focusing measurements also confirm this.

REPORT OF COMMITTEE E-5
ON
STANDING COMMITTEES

Since the last annual meeting, Committee E-5 on Standing Committees has held one meeting at Washington, D. C., in connection with the March committee meetings, at which it considered several matters respecting committee and Society procedure in the development and adoption of standards that were carried over from its report a year ago[1] and certain new matters, principally respecting committee membership, that had been referred to it by the Executive Committee of the Society for study and report.

The consideration given by the committee to these matters has led to certain modifications in the Regulations Governing Standing Committees, which, in accordance with the specified procedure, have been formally approved both by Committee E-5 and the Executive Committee. Since one of the proposed modifications involves an amendment of Article VI of the By-laws of the Society dealing with "Procedure Governing the Adoption of Standards," the Executive Committee is recommending to the Society that the proposed amendment be duly adopted in the manner provided for amendment of the By-laws.

The detailed modifications of the Regulations Governing Standing Committees are appended to this report. They have been duly submitted to a letter ballot vote of Committee E-5, which has resulted in their adoption by a vote of 38 affirmative and 1 negative, the negative vote applying only to the proposed revision of Section 15. By action of the Executive Committee the revised Regulations will become effective following the annual meeting.

In the following paragraphs the modifications are briefly discussed with explanation of considerations that have led to their adoption.

Committee Membership:

During the past few years questions of some importance have arisen on several occasions regarding the privileges and obligations of membership on committees, both on the part of individuals and on the part of companies, firms, corporations and associations. It has seemed desirable, therefore, to amplify the provisions of Section 2 of the Regulations Governing Standing Committees dealing with Appointments and Classifications of committee members. The following modifications have therefore been made:

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 608 (1927).

1. It is specifically stated that companies, firms, corporations and associations, as well as individuals, may hold membership. It has always been understood that any member of the Society is eligible to appointment on standing committees, whether individual or company, and this is now made specific.

2. It is required that companies, firms, corporations and associations holding membership on a standing committee shall appoint representatives acceptable to the committee. Companies can satisfactorily function in committee work only through persons appointed to represent them in the committee's activities and it is believed incumbent upon them, first, that they shall appoint duly authorized representatives and, secondly, that these representatives shall be acceptable to the committee.

3. It is required that applicants for membership shall furnish a suitable statement of their qualifications to serve upon the committee, and that this provision shall also apply to newly appointed representatives of company members on a committee.

4. Specific provision is made that action on applications for committee membership shall be either by vote of the standing committee or by the delegation of such authority to its advisory committee.

5. Experience in the functioning of several committees of the Society has indicated the desirability of a provision that change of employment of any member of the committee shall automatically terminate the membership, with the understanding that either the member or the committee may initiate steps for reappointment. A provision of this character has been made in the Regulations.

There has been considerable discussion respecting the control that a committee should have over the selection of representatives of company members of the committee. It is conceded that the company must have the right to designate the individual who is to serve as its representative; at the same time, since committee work is done actually by the men serving on the committee, it is essential that properly qualified individuals be placed on these committees whether they be members in their own name or representatives of company members. It is felt that the new provisions now embodied in the Regulations Governing Standing Committees will take care of this matter satisfactorily from the viewpoint both of the company and of the committee. Committee E-5 believes, however, that these Regulations should be interpreted in such a way as not to involve the actual election by the committee of newly designated representatives of companies, firms, etc., already holding membership on the standing committee, and the Executive Committee has confirmed that interpretation.

A minor modification in Section 4 of the Regulations dealing with Permanent Organization has been made to provide by name for the formation of advisory committees of our standing committees where desired. The growth of committee work has led in the majority of cases to the formation of such committees as the most convenient method of administrative direction of committee affairs.

Classification of Votes by Producers, Consumers and General Interests:

The matter of classification of votes was mentioned in the committee's report a year ago and has been under consideration during the past year. It had been suggested that letter ballot votes of the members of standing committees on all matters affecting standards be reported in such a way as to indicate the number of producers, consumers and general interests that have respectively cast affirmative or negative votes, or have asked to be recorded as "not voting." Committee E-5 finally concluded that the clerical work involved in the classification of votes in this way is not justified unless there develops a substantial negative vote on letter ballot, and it has modified Section 14 on Preparation of Standards to provide that this classification of votes shall be made when at least ten per cent of the affirmative and negative votes on any matter affecting standards has been cast in the negative.

Procedure at Annual Meetings Governing Adoption of Standards:

The committee reported a year ago that there had been under consideration a proposal that final approval by the Society of any revisions of the recommendations in a committee's report affecting standards as may be offered on the floor of the annual meeting should be contingent upon subsequent approval of such proposed modifications by letter ballot vote of the standing committee concerned. There has been noticed in recent years an increasing tendency on the part of committees to make important revisions in recommendations affecting standards contained in their formal reports, with the result that such recommended revisions have not received the required two-thirds approval by letter ballot vote of the whole committee. This practice is considered to be undesirable and Committee E-5 reaffirms the importance of strict adherence to the provision that, as required in Section 14 of the Regulations, there shall be reported to the Society the results of a letter ballot vote respecting all recommendations of the committee affecting standards. It is recognized, however, that contingencies arise where revisions seem desirable, and such revisions may, of course, be proposed independently of the committee itself on the floor of the annual meeting. The consideration of these matters by the committee during the year has led to a recommendation to the Executive Committee that approval of revisions of this character by the Society shall be contingent upon subsequent approval by letter ballot vote of the standing committee concerned; with the further provision that if the modifications thus referred to a subsequent letter ballot vote of the committee fail of approval, the original recommendations of the committee shall prevail and the proposed modifications be referred to the committee for study and report at the next annual meeting. An amendment of Article VI, Section 1 of the By-laws is required to put this provision into effect and upon the recommendation of Committee E-5 the Executive Committee has formally proposed that this amendment be approved by letter ballot vote of the Society.

Form of Letter Ballots:

Committee E-5 believes that it will be advantageous for committees to follow a standard form in conducting letter ballots on recommendations affecting standards, and a suitable form has been embodied in the Regulations as a part of Section 17 on Reports.

The committee has furthermore concluded that it is the duty of committee members in voting upon a committee report as a whole (as distinguished from individual recommendations within the report) to vote either affirmatively or negatively, but not to be recorded as "not voting." Whereas it is necessary, as the committee sees it, that opportunity be given for members to record themselves as "not voting" with respect to specific recommendations within the report, it is considered that every committee member has the responsibility of saying definitely whether or not he approves the submission of the committee's report as a whole to the Society. A provision to that effect has accordingly been included in Section 17.

In this connection it is pointed out that it is not inconsistent for a committee member to vote in the affirmative on the submission of the report as a whole although he may have voted in the negative with respect to some particular recommendation; the matter being one, of course, in which the committee member must be guided by his individual judgment.

Procedure in Sub-Committees Charged with Development of Standards:

As reported by the committee a year ago, there had developed some difference of opinion in Committee E-5 respecting the extent to which the Regulations Governing Standing Committees should go in prescribing the details of procedure of sub-committees. Those familiar with the committee work of the Society will realize that the increased size and scope of some of our larger committees have brought about an increase in the responsibility placed upon sub-committees of standing committees charged with the development of complete standards. The outcome of careful discussion of this matter during the past year has been a realization that it is more than ever incumbent upon each standing committee to give particular care to the formation of such sub-committees with respect both to the representative character of the personnel and the adequacy of the procedure that it follows; and moreover, that before acting on a standard reported by a sub-committee the committee shall assure itself that adequate action has been taken on the standard by the sub-committee. Sub-committees have no standing in the Society except through their parent committees, and the Society, therefore, must hold the parent committees fully responsible for the adequacy of consideration given by them and their sub-committees to standards that they offer to the Society.

It has been decided that no revisions in the Regulations are needed in respect to this matter and that this re-statement of the responsibility of the standing committees for the proper organization and procedure of sub-committees is sufficient.

Committee Meetings at Annual Meeting:

Several of the standing committees of the Society are beginning to arrange their activities in such a way that the committee meetings held during the annual meetings of the Society are devoted primarily to the development of plans for the next year's work rather than merely to a review of the work of the past year. Committee E-5 believes that this is a desirable policy; not only in that it serves to get the work of the new committee year planned and under way earlier than if the making of such plans is postponed until the fall, but also in that it will encourage more thorough consideration at the spring meeting of matters that the committee is planning to recommend to the Society in its annual report. It is believed that the spring meeting is the proper time to give careful and practically final consideration to the matters that are to go into the committee's annual report; and that revisions in that report should be made by the committee at the annual meeting only for the best of reasons. Committee E-5 therefore advocates the adoption of this plan by all the standing committees of the Society.

This report has been submitted to letter ballot vote of the committee, which consists of 41 members; 40 members returned their ballots, of whom 39 have voted affirmatively, none negatively, and 1 has marked his ballot "not voting."

Respectfully submitted on behalf of the committee,

C. L. WARWICK,
Chairman.

APPENDIX

REVISIONS IN THE REGULATIONS GOVERNING STANDING COMMITTEES[1]

(Approved Jointly by the Executive Committee and Committee E-5 on Standing Committees.)

The revisions that have been made in the Regulations Governing Standing Committees are given in detail below. The revision in Section 15, which is a quotation of Article VI, Section 1, of the By-laws, is dependent upon approval of the required amendment of that section of the By-laws by the Society. Words in italics have been inserted; words in brackets have been deleted.

Revise and rearrange Section 2 on "Appointments and Classifications" to read as follows:

2. **Appointments and Classifications.**—Appointments on standing committees shall be made by the Executive Committee subject to the following provisions:

(*a*) *Membership on standing committees may be held by individuals, and by companies, firms, corporations and associations. Companies, firms, corporations and associations holding membership on committees shall appoint representatives acceptable to the standing committee.* Only members of the Society shall be eligible, in general, to appointment on committees, although exceptions may be authorized by the Executive Committee in favor of representatives of government branches or other societies.

(*b*) [Additional] Appointments on *standing* [existing] committees shall be made only on the recommendation of, or with the approval of, such committees.

(*c*) *Applicants for membership on a standing committee, and newly appointed representatives of companies, firms, corporations and associations holding membership on a standing committee, shall furnish to the officers of the committee a statement of their qualifications to serve upon the committee.*

(*d*) *Action by a standing committee on applications for membership shall be by vote of the standing committee; or the standing committee may delegate such authority to its advisory committee.*

(*e*) *Change of employment of any member of a committee shall automatically terminate membership on such committee. A member losing membership because of change of employment, however, shall again be eligible for appointment in accordance with the provisions of these Regulations.*

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[1] The Regulations in their present form appear in the 1927 Year Book, pp. 317–324.

(*f*) Same as Paragraph (*a*) of present Section 2.

(*g*) Same as Paragraph (*b*) of present Section 2.

(*h*) Same as Paragraph (*c*) of present Section 2.

Revise Section 4 on "Permanent Organization" to read as follows:

4. **Permanent Organization.**—At the first meeting of a committee a permanent organization shall be effected by the election of a permanent chairman from among the consumers or general interests, and such other officers as the committee may desire, and the creation of such sub-committees, *including an advisory committee*, as may be desired. The duties and powers assigned to these officers and sub-committees, and the details of management and administration in general, shall be at the discretion of each committee, subject to the limitations of these Regulations.

Add the following sentence at the close of the first paragraph of Section 14 on "Preparation of Standards":

When at least ten per cent of the affirmative and negative votes by letter ballot on any recommendation affecting standards have been cast in the negative, the vote as announced to the Society shall be classified as to producers, consumers and general interests.

Revise Section 15 on "Procedure Governing the Adoption of Standards" by the addition of the following paragraph inserted between the third and fourth paragraphs of the present section:

Approval of modifications proposed on the floor of the annual meeting, of recommendations approved by the required letter ballot vote of the appropriate standing committee affecting standards and tentative standards, shall be contingent upon subsequent approval of such proposed modifications by letter ballot vote of the standing committee concerned; provided that if such proposed modifications fail of such subsequent approval, the original recommendations of the committee shall prevail and the proposed modifications be referred to the committee for study and report at the next annual meeting.

Revise the fourth, fifth and sixth paragraphs of Section 17 on "Reports" to read as follows:

The results of letter ballot votes of the committee on actions affecting standards shall be announced in the report of the committee (see Section 14). *A standard letter ballot form is given below.*

The report of a standing committee, before its presentation at the annual meeting, shall first have been submitted to letter ballot of the committee. *Members shall vote either affirmatively or negatively on the report*, and *the report* shall have received the approval of at least two-thirds of those voting.

A statement of the following form shall appear at the close of every committee report:

This report has been submitted to letter ballot of the committee, which consists of .... members; .... members returned their ballots, of whom .... have voted affirmatively *and* .... negatively [and .... have marked their ballots "not voting"].

LETTER BALLOT

Committee .... *Date* ....

Please vote on each item listed below and return ballot to the Secretary of this Committee promptly. A "Not Voting" column is provided for those who do not feel competent to vote on any one or all of the items submitted. Indicate your choice after each item in one of the three columns provided.

Items	Affirmative	Negative	Not Voting
I. New Tentative Standards			
II. Tentative Revisions of Existing Standards			
III. Proposed Revisions of Tentative Standards			
IV. Advancement of Tentative Standards to Standard			
V. Advancement to Standard of Tentative Revisions of Existing Standards			
VI. Withdrawal of Standards or Tentative Standards			

Note.—Where there are two or more representatives of a company membership, one Letter Ballot may be **signed** jointly by such representatives and counted as one vote.

Signature ....

....

Company ....

(*Member of Committee* ....)

REPORT OF COMMITTEE E-6
ON
PAPERS AND PUBLICATIONS

Since the last annual meeting the Committee on Papers and Publications has held two meetings, one on December 9, 1927, and the other on February 27, 1928. At these meetings certain routine matters of publication were taken care of, some general policies discussed and recommendations thereon made to the Executive Committee, and general arrangements and specific details of the program of this annual meeting considered. Some of the principal topics to be discussed at the meeting were agreed upon at the first meeting, and at the second meeting all offers of papers were passed upon for acceptance in accordance with the rules of the Society. Since that meeting the chairman and the Advisory Committee have acted for the committee on all matters relating to the program.

When the work was first begun on the technical program of this meeting the committee had been informed by the Executive Committee that it would be possible to increase the appropriation for the Proceedings to an extent that would allow the publication this year of from 150 to 200 pages more than in 1927. Making due allowance for a probable increase in the volume of committee reports, it was decided that a considerable proportion of the increased number of pages could be devoted to technical papers; with the result that the committee has been able to accept a number of papers practically one-third greater than a year ago. Due provision has been made for publication of discussions, which form a valuable part of the Proceedings. Even under this liberal procedure the committee was unable to accept all of the material offered to it. As in the past several years the committee has placed as nearly as possible a definite size limit on each paper commensurate with its nature and importance. It is a pleasure to record that the committee has had the cordial cooperation of the various authors in keeping their papers as closely as possible within the suggested limitations.

As this report is written, the program of the annual meeting has been in the hands of the members for some eight weeks. It is one of the largest and the committee believes one of the most interesting and important programs the Society has ever arranged. Some of the committee reports record accomplishments of outstanding value; and among the more important subjects discussed in the technical papers are: a study of cast-iron pipe; a critical discussion of methods of particle size determination; wear testing of metals, represented by four papers planned to introduce a general discussion; the properties of motor fuels and motor oils, introducing a discussion sponsored by Committee D-2 on Petroleum Products and Lubricants; corrosion and corrosion-fatigue of metals; testing of metals at elevated temperatures; the relation of strength of brick to strength of brick masonry; several papers on tests of cement; resistance of concrete to action of sulfate waters; and a number of papers discussing tests and properties of concrete, including workability, permeability and durability. The program this year is well-balanced between metals and non-metals and will, it is believed, make a wide and very general appeal to the membership.

Since the printing of the provisional program two reports and three papers were withdrawn and two papers were added. The final program of the meeting contains reports of 48 committees, including several joint committees and committees functioning under A.E.S.C. procedure; and 47 technical papers, including the annual address of the President and the Edgar Marburg Lecture, or a total of 95 items.

All of the reports containing recommendations affecting standards have been preprinted, although some of those reports were received so late that it has not been possible to mail copies in advance. For the most part the 7 reports not preprinted are in the nature of general progress reports. The only exception is the report of the Research Committee on Yield Point of Structural Steel. This committee found as the annual meeting drew near that it would be able to present a finished report on tests that had extended over the past two years; and the importance of this work is such that the Committee on Papers and Publications plans to issue reprints of it following the annual meeting to all who have requested copies.

Thirty-eight of the forty-seven papers have been preprinted. It is to be regretted that it was not possible to preprint all of them; but some of the manuscripts were received quite late, and this in conjunction with the considerable volume of material in hand has made it impossible to print everything in advance.

The total number of pages preprinted, estimated at 1346, is the largest for any annual meeting of the Society. The reports and papers not yet printed will occupy approximately 45 and 155 pages respectively, bringing the total number of pages of reports and papers on the program to 1546.

It is interesting to compare the volume of reports and papers for this year with those for the two preceding meetings. This comparison is given below:

	1926	1927	1928
REPORTS:			
Total Number	36	49	48
Number of Preprints	32	46	41
Pages Preprinted	848	887	801
PAPERS:			
Total Number	38	32	47
Number of Preprints	17	31	38
Pages Preprinted	258	373	545
TOTAL REPORTS AND PAPERS:			
Total Number	74	81	95
Number of Preprints	49	77	79
Pages Preprinted	1106	1260	1346

The arrangement of the program follows in general that adopted several years ago, which has seemed to work out quite satisfactorily. The details of presentation of reports and papers, including the observation in so far as possible of a time schedule in each session, initiated several years ago, will again be followed.

Several matters of publication policy were considered that deserve a word of mention. The committee has recommended to the Executive Committee of the Society that there be published annually a combined index of standards and tentative standards, as a means of increasing the effectiveness and usefulness of the Society's specifications and making reference to them more readily available. It is believed such an index would be of real value to the members. It has also been recommended that this volume if published be given rather wide distribution among purchasing agents and others who could use A.S.T.M. specifications to advantage in the purchase of materials.

The committee will also lend its encouragement to any standing committees of the Society who desire to arrange for the printing in quantity of special pamphlets embodying the group of standards they have prepared for the Society, together possibly with their current annual reports. During the past year several committees arranged for the publication of such reprints by underwriting the cost among their members. It is believed that the publication of these reprints has been particularly useful to the members of the committees and it has undoubtedly served effectively to disseminate these groups of standards throughout the interested industries.

At the annual meeting of the Society last year attention was called at one of the sessions to the fact that in certain papers there presented, results of tests were reported that were out of line with the standard tests established by the Society, thus making it difficult to compare the results reported with results which might be reported elsewhere. Committee E-6 was asked to consider the possibility of calling the attention of authors to the desirability of reporting results wherever possible in accordance with the standard A.S.T.M. methods. The committee has taken favorable action upon this suggestion, and this matter will hereafter, more or less as a matter of routine, be called to the attention of prospective authors of papers.

The committee has given consideration during the year to certain changes in the form and arrangement of the Year Book of the Society necessitated in part by the steady increase in size of that book. In the Year Book for 1928 the list of members will accordingly be set in double column, using a pleasing and very readable style of type. This change will reduce by approximately 25 per cent the space taken by the list of members. Other changes in arrangement and typography of the list of members of committees of the Society are under consideration. The most important of these is a rearrangement of committee personnel by which the members will be listed in strictly alphabetical order irrespective of classification of producer or non-producer; and their classification under the new regulations as producer, consumer or general interest will be indicated by the appropriate letter placed in front of their names. The list will also include by cross reference names of individuals who represent company members.

To an increased degree the committees of the Society are arranging for the presentation at their meetings of papers by members and others, which may or may not be included later in their annual reports to the Society. Where such papers are not thus included it will be the policy of the Committee on Papers and Publications to list such papers by title and to indicate where they may have been published. Three such papers were presented at the meeting of Committee D-13 on Textile Materials in Providence on March 8 and 9 and appear in the issue of the *Textile World* for March 17, as follows: "A Strength Test for Knitted Fabrics," by W. H. Whitcomb; "A Practical Program for Humidity in Textiles," by G. B. Haven; and "Genetics in Textile Research," by W. F. Edwards.

Respectfully submitted on behalf of the committee.

C. L. WARWICK,
Chairman.

REPORT OF COMMITTEE E-8
ON
NOMENCLATURE AND DEFINITIONS

The work of Committee E-8 during the past year has been full of interest and considerable progress has been made in the review of definitions of terms and the correlation of definitions prepared by the several standing committees. Much of this work has been carried out by the special Editorial Committee of the Advisory Committee which committee carries on much of the preliminary editorial review on the various definitions, and discusses suggested modifications with the standing committees concerned. Those definitions that affect two or more of the standing committees of the Society are handled by representative sub-committees and these sub-committees are this year recommending the advancement to standard of several definitions under the immediate jurisdiction of Committee E-8. The work continues to be such that it can be handled for the most part by correspondence, requiring only one general meeting of the committee to pass upon definitions being recommended by the standing committees concerned for advancement to standard. The committee has continued the practice of the past few years of holding this meeting late in the year, after the meetings of other committees, so as to take action on the definitions which the standing committees may be recommending for advancement to standard. This meeting was held on May 11.

The committee, in this report, wishes again to call attention to the service it is prepared to render to standing committees in the preparation of definitions. Several of the standing committees have taken advantage of the fact that Committee E-8 is prepared to act in an advisory capacity in the preparation of definitions and have submitted to the committee definitions that are under consideration, in order that they be reviewed while they are still in a formative or sub-tentative stage, looking to Committee E-8 for suggestions on the form of the definitions and conciseness and clarity of wording. All definitions must receive the review and approval by Committee E-8 before adoption as standard, and to have them reviewed by the committee before their submission as tentative should result in their being submitted in a more nearly final form. Such a procedure is one that should be encouraged, and all standing committees are invited to submit definitions for comment as soon as there is any suggestion that they may ultimately be submitted before the Society as tentative definitions.

In all, Committee E-8 has now approved 149 definitions as standard. It still has 94 tentative definitions before it for review and in addition there are 218 standard definitions that have not received the review and approval of the committee. Twenty definitions are being approved by Committee E-8 this year. With these, Committee E-8 will have approved 169 definitions of terms. The definitions continued as tentative and those being recommended for adoption are discussed below in greater detail and the work of the several sub-committees is presented.

Glossary of Terms.—In view of the large number of definitions already approved by Committee E-8, to which should be added the 218 definitions which had already been adopted as standard when Committee E-8 was first organized, the committee recommended a year ago that a glossary be published, to be included in the Book of Standards, of all the standard definitions of the Society. A further glossary was recommended of all tentative definitions of terms for inclusion in the Book of Tentative Standards. The preparation of the glossaries was approved and the work of compilation has proceeded during the year. Questions of form and of general arrangement have been decided and the work that has been carried out has indicated the desirability of publishing a combined glossary of all standard and tentative definitions of terms. The committee is not yet prepared to publish the glossary, believing that comments and suggestions should be received on a tentative draft before publication is attempted, but the glossary will be issued in mimeograph form to the members of Committee E-8, and to others upon request, during the next few months.

DEFINITIONS OF TERMS APPROVED BY COMMITTEE E-8

As a matter of record, a complete list of the 149 terms approved by Committee E-8 is included, as given below:

Absolute Specific Gravity (of solids and liquids)
Accelerator
Aging Coefficient
Alberts
Alloy
Alpha Brass
A.S.T.M. Paraffin Wax Melting Point
A.S.T.M. Petrolatum Melting Point
Apparent Specific Gravity (of Solids)
Army Duck
Ash
Asphalt Mastic
Asphalt Mastic Cake
Bad Start-up
Baggy Fabric
Balata Belt Duck
Beta Brass
Binder
Bituminous Grout
Book Tile
Bulk Specific Gravity (of solids)

Calcined Gypsum
Cells
Cement
Chafed Cord
Clay
Clay (in the case of textiles)
Clay Separate
Coercive Force
Cord
Core Loss
Corkscrew Twist
Correction
Count
Crimp
Crushed Gypsum
Defective Splice
Direction of Twist
Drills
Drying Oil
Enamel
Enameling Duck
End-Construction Tile
Ends
Equi-axed Grain
Error
Etching Reagent
Filler
Fire Clay
Fixed Carbon
Float
Foundation Tile
Furring Tile
Grain
Grain Size
Gypsum
Gypsum Plastering Sand
Hollow Floor Tile
Hollow Tile
Hollow Tile Fireproofing
Hose Duck
Imperfect Selvage
Irregular Pick
Jeans
Kink
Knot
Lake
Lath
Lea
Length
Load Bearing Wall Tile
Loading Range
Macrograph
Magnetic Permeability
Magnification
Mechanical Fabric
Metal
Metallography
Micrograph
Mispick or Broken Pick
Missing Cord
Missing Warp (Yarn or Cord)
Moisture
Moisture Content (Moisture, Percentage of Moisture) (in the case of textiles)
Mortar
Non-Drying Oil
Normal Induction
Numbered Duck
Off-Square
Oil Belt Duck
Organic Acetone Extract
Partition Tile
Percentage of Error
Picks
Plain Weave
Plaster
Porous Hollow Tile
Proximate Analysis
Pucker (Puff or Blister
Reed Mark
Residual Induction
Retarder
Rubber Belt Duck
Salt-Glazed Tile
Saponifiable Acetone Extract
Scoring
Semi-Drying Oil
Serge
Sewed Yarn
Shale
Shell
Side-Construction Tile
Single Filled or Flat Duck
Size
Sized Gypsum
Slack and Tight Warp or Filling Yarns or Cords
Slate
Slug
Smash
Specific Gravity (of solids and liquids)
Split Tile

Split or Chafed Yarn or Cord
Standard Atmosphere
Standard Condition
Standard Core Loss
Standard Regain
Standard Weight
Stucco
Surface Clay
Testing Machine
Thick and Thin Places (Major Defects)
Thick and Thin Places (Minor Defects)
Thickness
Thread
Tire Builder Fabric
Tire Cord Fabric
Tolerance
Toner
Total Waxy Hydrocarbons
Twill
Ultimate Analysis
Unsaponifiable Resins
Varnish
Volatile Matter
Webs
Width
Wood Fiber
Wrong Draw
Yarn

In addition to the 101 terms listed in the report of the committee for 1927, the above list includes 48 additional terms adopted at the 1927 annual meeting.

TENTATIVE DEFINITIONS BEFORE COMMITTEE E-8

As mentioned above, 48 tentative definitions were adopted as standard at the 1927 annual meeting. Thirty-nine new tentative definitions were submitted as follows:

Definitions Relating to Heat Treatment:

Heat Treatment
Quenching
Hardening
Annealing
Normalizing
Spheroidizing
Tempering (also termed Drawing)
Malleablizing
Graphitizing
Carburizing (Cementation)
Case Hardening
Case
Core
Cyaniding

Definitions Relating to Refractories:

Plastic or Bond Fire Clay
Flint Fire Clay
Diaspore Clay
Nodular Fire Clay
Spalling
Pyrometric Cone Equivalent (P. C. E.)

Definition Relating to Paint:

Leafing

Definitions Relating to Petroleum Products:

Average Sample
All-Levels Sample
Upper Sample
Middle Sample
Lower Sample
Composite Sample
Continuous Sample
Dipper Sample
Mixed Sample
Thief Sample
Drain Sample
Bottom Sample
Borings Sample
Grab Sample

Definitions Relating to Electrical Insulating Materials:

Power Factor
Dielectric Constant
Loss Factor

Definition Relating to Textiles:

Loop Knot

Thirteen definitions were withdrawn, incorporated with other definitions, or classed by Committee E-8 as not definitions, as follows:

Quenching Charge (A 18)
Annealing Charge (A 18)
Billet (A 17)
Tempering Charge (A 18)
Merchant Bar Iron (A 81)
Knot of Finished Cord (D 179)
Slack and Tight Cords (D 179)
Thin Places (Major) (D 179; D 122)
Thin Places (Minor) (D 179; D 122)
Annealing (A 95)
Normalizing (A 95)
Ductility (D 113)
Specific Gravity (D70; D 71)

This left 94 tentative definitions before Committee E-8 for consideration. Grouped below according to subject matter the present status of these definitions is indicated.

Term Relating to Heat Treatment Operations (A 119).—The 14 terms defined by Committee A-4 on Heat Treatment of Iron and Steel are as follows:

Heat Treatment
Quenching
Hardening
Annealing
Normalizing
Spheroidizing
Tempering
Malleablizing
Graphitizing
Carburizing (Cementation)
Case Hardening
Case
Core
Cyaniding

These definitions are still under consideration in Committee E-8. No comments or suggestions have as yet been forwarded to Committee A-4 but it is planned to discuss these definitions with that committee in some detail during the coming year.

Terms Relating to Lime (C 51, C 25).—The 7 terms defined by Committee C-7 on Lime are as follows:

Quicklime
Hydrated Lime
In Bulk
Lump Lime
Lump Lime Screened
Pulverized Lime
Available Lime

The definition for the term "available lime" appears in the Tentative Methods of Chemical Analysis of Limestone, Quicklime and Hydrated Lime (C 25). Suggestions have been transmitted to Committee C-7 in reference to this definition but, since the methods in which it appears are not being recommended for advancement to standard, no action is being taken on this definition by Committee E-8 at the present time.

The remaining definitions, which appear in the Tentative Definitions of Terms Relating to Lime (C 51) are being recommended for advancement to standard. These had previously been discussed with Committee C-7 and it is the understanding of Committee E-8 that Committee C-7 plans to withdraw one of these definitions, namely, for the term "in bulk." Committee E-8 approves the advancement to standard of the remaining definitions, proposing modifications, however, in the terms "lump lime screened" and "pulverized lime," to eliminate certain specification requirements. These revised wordings are as follows:

Lump Lime Screened.—Lump lime after forking or screening to remove the finer portion.

NOTE.—The portion removed is usually that which will pass a ½-in. sieve.

Pulverized Lime.—Quicklime which will pass a fine sieve of specified size.

NOTE.—The size of the sieve is usually ¼-in.

Terms Relating to Refractories (*C 71*).—The 6 terms defined by Committee C-8 on Refractories are as follows:

Plastic or Bond Fire Clay
Flint Fire Clay
Diaspore Clay
Nodular Fire Clay
Spalling
Pyrometric Cone Equivalent (P.C.E.)

Agreement had been reached between Committee E-8 and Committee C-8 on the definitions for the first four terms, namely, "plastic or bond fire clay," "flint fire clay," "diaspore clay" and "nodular fire clay," and these are being recommended for advancement to standard by Committee C-8 in their proposed modified form, the advancement to standard meeting with the approval of Committee E-8. The remaining two terms, namely, "spalling" and "pyrometric cone equivalent (P. C. E.)" are still under discussion.

Terms Relating to Gypsum.—The 8 terms defined by Committee C-11 on Gypsum are as follows:

Aggregate (C 11)
Consistency (C 11)
Gypsum Molding Plaster (C 11, C 59)
Gypsum Plaster Board (C 11, C 37)
Gypsum Pottery Plaster (C 11, C 60)
Gypsum Wall Board (C 11, C 36)
Keene's Cement (C 11, C 61)
Plasticity (C 11)

Committee C-11 is recommending the advancement to standard of 5 definitions of terms, namely, "gypsum molding plaster," "gypsum pottery plaster," "Keene's cement," "gypsum plaster board" and "gypsum wall board." These had been under discussion between Committee C-11 and Committee E-8 and the advancement to standard of three of these terms was approved by Committee E-8, namely, the definitions for "gypsum molding plaster," "gypsum pottery plaster," and "Keene's cement." The definitions for "gypsum plaster board" and "gypsum wall board" have, however, been referred back to Committee C-11 for further consideration.

The definitions for "consistency" and "plasticity" are under consideration in a technical committee of Committee E-1 on Methods of Testing. This committee has made substantial progress during the past year on the preparation of definitions for these two terms.

In respect to the definition for "aggregate," a definition for this term is being recommended for advancement to standard this year by Committee E-8, prepared by the Sub-Committee on Sand and Aggregate. This definition, it is understood, is satisfactory to Committee C-11 and that committee's definition will, no doubt, be brought in line with the standard definition during the coming year.

Terms Relating to Paint (D 16).—Committee D-1 on Preservative Coatings for Structural Materials has still before it 3 tentative definitions submitted several years ago, namely, definitions for the terms "toughness," "elasticity of paint and varnish films" and "screen (sieve)." Revisions of these terms are being recommended this year by Committee D-1, to bring them in line with the suggestions of Committee E-8. They are not, however, being recommended for advancement to standard this year and no action on their approval has been taken by Committee E-8.

A definition for the term "leafing" was submitted last year as a part of the Tentative Specifications for Aluminum Powder for Paints (D 266). This definition is still under consideration in Committee E-8.

Terms Relating to Petroleum Products.—The following 20 terms appear in the methods of test prepared by Committee D-2 on Petroleum Products and Lubricants:

Alkali Neutralization Number (D 188)
A.S.T.M. Precipitation Number of Lubricating Oils (D 91)
Cloud Point of Petroleum Oil (D 97)
Mineral Acid Neutralization Number (D 188)
Neutralization Number (D 188)
Pour Point of Petroleum Oil (D 97)
Average Sample (D 270)
All-Levels Sample (D 270)
Upper Sample (D 270)
Middle Sample (D 270)
Lower Sample (D 270)
Composite Sample (D 270)
Continuous Sample (D 270)
Dipper Sample (D 270)
Mixed Sample (D 270)
Thief Sample (D 270)
Drain Sample (D 270)
Bottom Sample (D 270)
Borings Sample (D 270)
Grab Sample (D 270)

Agreement had been reached between Committee D-2 and Committee E-8 on the definitions for "A.S.T.M. precipitation number of lubricating oils," "cloud point of petroleum oil" and "pour point of petroleum oil" and these are being recommended for advancement to standard by Committee D-2, Committee E-8 recommending, however, the omission of the phrase "of petroleum oil" in the definitions for cloud point and pour point. With this slight modification, Committee E-8 approves the advancement to standard of these three terms.

The remaining terms are still under discussion.

Terms Relating to Coal and Coke (D 121).—The 5 terms defined by Committee D-5 on Coal and Coke are as follows:

Coke
Beehive Coke
By-Product Coke
Coke Breeze
Dry Coke

Revisions of these definitions of terms are still under consideration in Committee D-5.

Terms Relating to Insulating Materials (*D 150, D 257*).—The 8 terms defined by Committee D-9 on Electrical Insulating Materials are as follows:

Power Factor
Dielectric Constant
Loss Factor
Insulation Resistance
Volume Resistance
Surface Resistance
Volume Resistivity
Surface Resistivity

These definitions are satisfactory to Committee E-8 in their present form. They are not, however, being recommended for advancement to standard this year and no action on their approval has been taken by Committee E-8.

Terms Relating to Textiles (*D 123, D 258*).—The 10 terms defined by Committee D-13 on Textile Materials are as follows:

Loop Knot
Gage
Regain (Moisture Regain)
Rayon
Rayon Yarns
Spun Rayon
Nitro-Cellulose Rayon (Chardonnet)
Viscose Rayon
Cuprammonium Rayon
Cellulose-Acetate Rayon

The definitions for the terms "loop knot," "gage" and "regain (moisture regain)" are being recommended for advancement to standard this year by Committee D-13. Committee E-8 approves the advancement to standard of the definitions for the first two terms, modified slightly to read as follows:

Loop Knot.—Snarl or curl produced by a filling yarn coiling upon itself.

Gage.—In the case of knit goods, a measure of the fineness of the fabric as determined by the closeness of the wales, that is, the longitudinal rows of loops.

NOTE.—It is expressed by the number of wales or needles in 1½ in.

The definition of the term "regain (moisture regain)" also recommended for advancement to standard by Committee D-13 was referred back to Committee D-13 for further consideration. The remaining definitions are still under consideration in Committee D-13.

Terms Relating to Methods of Testing.—Definitions for the following 8 terms, prepared by Committee E-1 on Methods of Testing, appear in the Tentative Definitions of Terms Relating to Methods of Testing (E 6), in the Tentative Methods of Compression Testing of Metallic Materials (E 9), and in the Tentative Methods of Tension Testing of Metallic Materials (E 8).

Stress
Strain
Stress-Strain Diagram
Elastic Limit
Yield Point
Tensile Strength
Compressive Strength
Modulus of Elasticity

These definitions are still under discussion between Committee E-1 and Committee E-8. No recommendation is being made this year for the advancement to standard of these definitions.

Miscellaneous Terms.—There are 4 terms classed as miscellaneous:

Sand (C 58)	Screen (Sieve) (E 13)
Aggregate (C 58)	Concrete Brick (C 55)

The definitions for the first three terms are recommended for advancement to standard as indicated under the activities of the Sub-Committees on Sand and Aggregate and on Sieve and Screen.

The definitions for the term "Concrete brick" appears in the present Tentative Specifications for Concrete Building Brick (C 55). These specifications are being superseded by new specifications which do not include a definition for this term.

ACTIVITIES OF SUB-COMMITTEES

Sub-Committee on Definitions of the Terms Sieve and Screen.—The Sub-Committee on Sieve and Screen, under the chairmanship of L. R. Ferguson, had published in 1925 a definition of the term "screen (sieve)," which was revised as to form in 1926.[1] On the recommendation of this sub-committee the definition is now being recommended for advancement to standard. Two slight modifications, however, are being made, namely, the inclusion of the phrase "or other device" after the phrase "A plate or sheet or a woven cloth," in order to make the definition apply to all types of screens used, including bar screens and riddles, and changing the word "materials" to "material." The definition as recommended for advancement to standard is as follows:

Screen (*Sieve*).—A plate or sheet or a woven cloth, or other device, with regularly spaced apertures of uniform size, mounted in a suitable frame or holder, for use in separating material according to size.

NOTE 1.—The shape and spacing of apertures, size of wires or threads, thickness of plate or sheet, allowable variations and similar properties should be taken care of in specifications.

NOTE 2.—In mechanical analysis testing work, when not otherwise specified, the term "sieve" shall apply to an apparatus in which the apertures are rectangular, and the term "screen" shall apply to an apparatus in which the apertures are circular.

Sub-Committee on Definitions of the Terms Sand and Aggregate.—The sub-committee, under the chairmanship of L. R. Ferguson, had published in 1924, and revised in 1926,[2] a definition for the term "sand." On the recommendation of this sub-committee the definition is now being recommended for advancement to standard with a slight modification in the note to the definition, to omit the quotation marks on the word "sand" and using instead the phrase "the term sand." This modification is made for the sake of consistency, in order to have explanatory notes to definitions in the same form. The definition as recommended for advancement to standard reads as follows:

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, p. 1091 (1926); also 1927 Book of A.S.T.M. Tentative Standards, p. 752.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol 26, Part I, p. 787 (1926); also 1927 Book of A.S.T.M. Tentative Standards, p. 232.

Sand.—The fine granular material (usually less than ¼ in. in diameter) resulting from the natural disintegration of rock, or from the crushing of friable sandstone rocks.

NOTE.—When used without a qualifying adjective, the term sand is generally understood to mean the product of the natural disintegration of siliceous or calcareous rock. Sand should be distinguished from screenings, gravel, etc. The size of particle and other physical characteristics should be taken care of in specifications. The fine material resulting from the crushing of blast-furnace slag is known as "slag sand."

The sub-committee published as tentative in 1926[1] a definition for the term "aggregate" which definition was continued in 1927 without change. It is now recommended that this definition be advanced to standard, changing the word "agglomerated" to "conglomerated" in order to make the definition consistent with the wording of the proposed definition for "concrete," and inserting an introductory clarifying phrase "in the case of materials of construction" in order to distinguish the intended use of this definition from other engineering uses of the term "aggregate" such as in metallographic work, and changing the word "concrete" to "concretes," in order to make clear that the definition applies to aggregates used in all types of concrete. The definition as recommended for advancement to standard reads as follows:

Aggregate.—In the case of materials of construction, designated inert material, which when bound together into a conglomerated mass by a matrix forms concretes, mastic, mortar, plaster, etc.

The sub-committee has under consideration the preparation of definitions for the terms "gravel," "crushed gravel" and "screened crushed gravel." Substantial progress has been made during the year on the preparation of definitions for these three terms but a further study will need to be made concerning the use of the term "crushed gravel" before the submission of definitions.

Sub-Committee on Definition of the Term Concrete.—The sub-committee, under the chairmanship of L. R. Ferguson, submitted in 1926, a definition for the term "concrete" which was published in the report of Committee E-8 for that year as information as follows:

Concrete.—A combination of aggregate or aggregates with a binding medium which, after mixing, solidifies into a conglomerate mass.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, p. 787 (1926); also 1927 Book of A.S.T.M. Tentative Standards, p. 232.

NOTE.—In the present state of the art, the term concrete, when used without a qualifying adjective, is understood to mean portland-cement concrete.

It was continued as information in 1927. The Editorial Committee reviewed the definition and suggested a modification. The sub-committee offers a revised wording which is published herewith as information in order to elicit comments and suggestions before submitting the definition for publication as tentative:

Concrete.—A mixture of aggregate or aggregates and a binding medium which solidifies into a conglomerate mass.

NOTE.—In the present state of the art, the term concrete, when used without a qualifying adjective, is understood to mean portland-cement concrete.

DEFINITIONS IN PREPARATION REFERRED TO COMMITTEE E-8

Definition of the Term Brick.—Committee C-3 on Brick last year published as information a definition for the term "brick." During the year it has referred this definition to Committee E-8. Committee E-8 has voted to take over the development of the definition for this term as requested by Committee C-3 and proposes to organize a sub-committee consisting of the representatives of the standing committees interested in the development of such a definition.

In order to elicit comment and suggestions for the benefit of the proposed sub-committee, the committee offers the following definition as information:

Brick.—A material of construction in small regular units, solid or practically so, formed from inorganic substances and hardened in a shape approximating a rectangular prism.

NOTE.—In the present state of the art, the term brick, when used without a qualifying adjective, is understood to mean a unit of burned clay or shale. When other substances are used the term brick should be suitably qualified. In the United States, building brick are usually 8 by $3\frac{3}{4}$ by $2\frac{1}{4}$ in. in size.

Definitions of Terms Relating to Timber.—Committee D-7 on Timber has had in preparation during the past few years a number of definitions of terms relating to timber. These definitions, when adopted as standard, will supersede a number of definitions formerly published in the Specifications for Structural Douglas Fir, which specifications were withdrawn in 1926, and are intended to replace some of the definitions now appearing in the Definitions of Terms Relating to Structural Timber (D 9). Committee D-7 referred the suggested definitions to Committee E-8 and a number of suggestions were forwarded to Committee D-7. The committee has modified its definitions in the light of these suggestions and it is expected that the definitions will be submitted as tentative next year.

The committee has re-elected the present officers to serve for the ensuing term of two years.

The approval of the definitions being recommended for advancement to standard and the recommendations appearing in this report have been referred to letter ballot of the committee with the following results, 34 having returned their ballots:

Items	Affirmative	Negative	Not Voting
I. PUBLICATION AS INFORMATION IN THE REPORT OF COMMITTEE E-8			
1. Definition of Term Concrete	25	2	7
2. Definition of Term Brick	22	1	11
II. ADVANCEMENT TO STANDARD OF TENTATIVE DEFINITIONS			
3. Definition of Term Screen (Sieve)	26	2	6
4. Definition of Term Sand	26	0	8
5. Definition of Term Aggregate	27	1	6
III. APPROVAL OF ADVANCEMENT TO STANDARD OF TENTATIVE DEFINITIONS, RECOMMENDED BY STANDING COMMITTEES			
6. Definitions of Terms Relating to Lime:			
Quicklime	24	0	10
Hydrated Lime	23	1	10
Lump Lime	24	0	10
Lump Lime Screened	24	0	10
Pulverized Lime	23	1	10
7. Definitions of Terms Relating to Refractories:			
Plastic or Bond Fire Clay	22	0	12
Flint Fire Clay	22	0	12
Diaspore Clay	22	0	12
Nodular Fire Clay	22	0	12
8. Definitions of Terms Relating to Gypsum:			
Gypsum Molding Plaster	22	0	12
Gypsum Pottery Plaster	22	0	12
Keene's Cement	22	0	12
9. Definitions of Terms Relating to Petroleum Products:			
Cloud Point	24	0	10
Pour Point	24	0	10
A.S.T.M. Precipitation Number of Lubricating Oils	24	0	10
10. Definitions of Terms Relating to Textiles:			
Loop Knot	17	0	17
Gage	17	0	17

This report has been submitted to letter ballot of the committee, which consists of 47 members; 38 members returned their ballots, of whom 37 have voted affirmatively, none negatively, and one has marked his ballot not voting.

Respectfully submitted on behalf of the committee,

CLOYD M. CHAPMAN,
Chairman.

R. E. HESS,
Ex-Officio Secretary.

EDITORIAL NOTE

The Tentative Definition of the Term Sand as revised by the committee was approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on September 1, 1928, and appears in the 1928 Supplement to Book of A.S.T.M. Standards.

The Definition of the Term Screen (Sieve); and of the Term Aggregate were not adopted as recommended by the committee, but were continued as tentative in their proposed revised form.

REPORT OF COMMITTEE E-9
ON
CORRELATION OF RESEARCH

During the year Committee E-9 on Correlation of Research has held two meetings, one on October 10, 1927, and one on April 9, 1928, both in the Society rooms at Philadelphia.

During the year the "List of Current and Proposed Researches and Investigations by A.S.T.M. Committees" has been kept abreast of the reported work of the various standing committees. This list is in card index form and is on file in the Secretary's office.

There is appended to this report a list of the titles and brief statements of research projects from which the volume and extent of the research work now being done under the auspices of the Society is apparent. The list does not include new projects initiated since the 1927 annual meeting. Information regarding any project is maintained by the committee and will gladly be furnished to any member or committee of the Society upon request. Most of the listed projects are active.

During the past year F. G. Breyer has resigned his membership on the committee and the resulting vacancy has been filled by the appointment of F. R. McMillan, Director of Research of the Portland Cement Association, Chicago, Ill.

Term of Membership in Committee E-9:

Up to this year the members of Committee E-9 were appointed for indefinite terms of service. It has seemed desirable to the committee that the term of service of the members be fixed at five years, and that one member retire each year with the appointment of a new member to take his place. The Executive Committee of the Society approved this plan and voted that the assignment of retiring dates for the present members be decided by lot. This has been done and the terms of the members expire as follows:

Term expiring June, 1929—G. H. Clamer
" " " 1930—H. F. Moore
" " " 1931—G. K. Burgess
" " " 1932—F. E. Schmitt
" " " 1933—F. R. McMillan

Research Committees of the Society:

Research Committee on the Effect of Tin and Arsenic on High-Speed Tool Steels.—Owing to illness of the chairman the work of this committee has been very greatly hindered this year. With his restoration to health the work of the committee will, it is expected, be resumed vigorously.

Research Committee on Yield Point of Structural Steel.—The work of this committee is in an active state. A series of tests of specimens from various parts of steel structural shapes has been completed and the data are being digested. It is hoped that this series of tests will throw some light on the possibility of obtaining, by careful test methods, significant values of the yield point of steel from structural shapes.

Research Committee on Effect of Temperature on the Properties of Metals.—This committee functions under the joint auspices of this Society and the American Society of Mechanical Engineers. The committee has been making check tests to confirm certain conclusions from the first series of short-time tests under various temperatures, upon which substantial progress was reported a year ago, and is planning fatigue tests under elevated temperatures. The work of the committee is in a decidedly active state.

Joint Committee on Investigation of the Effect of Phosphorus and Sulfur in Steel.—This committee functions under the joint auspices of a number of organizations and is making substantial progress in its work. At present it is engaged in the study of effect of sulfur on certain grades of forging steel and on the effect of phosphorus on carbon steel for castings. Consideration is being given to the study of the effect of added phosphorus on low-carbon steel such as is used for welded steel pipe.

Proposed Research Committee on Fatigue Phenomena in Metals.—The National Research Council Committee on Fatigue Phenomena of Metals has been discharged by that body, with the suggestion that its work be carried on by other technical societies. Acting on the suggestion of Committee E-9, the Executive Committee of the Society has authorized the formation of a Research Committee on Fatigue Phenomena in Metals, to have the broad functions to conduct, correlate and summarize research in the fatigue of metals and to report annually to the Society on this subject. A nucleus group will meet during this annual meeting to discuss the general lines of work proper for such a committee and the plans of organization. The decision to form this committee is an important step in carrying forward the policies of the Society in furthering its purpose of promoting knowledge of engineering materials.

Research in Magnetic Analysis:

Committee A-8 on Magnetic Analysis was organized as a regular standing committee, but its contribution to the work of the Society has been almost wholly along the lines of research. It has made many valuable contributions, and it is with satisfaction that Committee E-9 notes that the Dudley medal this year goes to A. V. de Forest for a paper which records some of his brilliant work in magnetic analysis, and which was written with the encouragement and in the spirit of the work of Committee A-8. The work of that committee, with the papers published with its encouragement, is an excellent example of research work done by a standing committee of the Society.

Committee on Iron-Chromium-Nickel Alloys:

Two years ago, at the suggestion of Committee E-9, Committees A-5 on Corrosion of Iron and Steel and B-3 on Corrosion of Non-Ferrous Metals and Alloys formed a joint advisory committee to consider the method and scope of work in the field of corrosion-resistant alloys. During the group meetings at Washington this spring, the joint advisory committee met, with the chairman and secretary of Committee E-9 present by invitation, and after discussion voted to request the Executive Committee of the Society to authorize the formation of a standing committee to study the alloys of the iron-chromium-nickel system, the committee to have adequate representation from both consuming and producing interests and to function under a scope that includes studies of all properties of the alloys in this system. Committee E-9 at its April meeting seconded this request with the note that research work in this field was to be a part of the function of the proposed committee. The Executive Committee has authorized the formation of this standing committee. The iron-chromium-nickel alloys fall in the region between the recognized fields of Committees A-5 and B-3 and there seems to be a fertile field for the new committee.

New Research Activities by Standing Committees:

The following new projects, described in the Appendix to this report, were announced by the respective committees in their 1927 annual reports:

Committee A-5 on Corrosion of Iron and Steel:
S 50 Metal Culvert Corrosion Tests.

Committee B-2 on Non-Ferrous Metals and Alloys:
S 58 Investigation of Die-Casting Alloys.

Committee B-3 on Corrosion of Non-Ferrous Metals and Alloys:
S 45 Atmospheric Corrosion of Non-Ferrous Metals and Alloys.
S 46 Corrosion of Non-Ferrous Metals and Alloys in Liquids—Field Tests.
S 47 Galvanic and Electrolytic Corrosion of Non-Ferrous Metals and Alloys.

Committee B-4 on Metallic Materials for Electrical Heating:
S 48 Growth of Nickel-Chromium Resistor Materials Due to Continued and Repeated Heating.
S 49 Life Test for Durability of Electrical Resistance Wire at High Temperatures.

Committee D-11 on Rubber Products:
S 54 Abrasion Tests of Rubber Products.
S 55 Life Tests of Rubber Products.
S 56 Flexing Tests of Rubber Products.
S 57 Shock Absorption of Rubber Products.

Committee D-16 on Slate:
S 51 Abrasive Hardness of Slate.
S 52 Weathering Characteristics of Slate.
S 53 Investigation of Sand Used for Rubbing Slate.

The four investigations named under Committee D-11 represent a division of the project initiated several years ago dealing with the general subject of Performance Tests of Rubber Products. The work has developed to such an extent as to necessitate the formation of separate sub-committees to handle the respective studies.

Some Subjects Under Discussion:

Wear Testing of Metals.—The committee believes that from an economic point of view wear of metals is perhaps second in importance only to corrosion of metals, and has been giving consideration to the possibility of establishing means within the Society for concerted study of this problem. At its suggestion the Committee on Papers and Publications has arranged for the presentation of several papers on the subject at this annual meeting.

Mineral Aggregates.—The committee reported a year ago that discussions with a number of users of mineral aggregates, several technical societies and one or two government bureaus had led to the conclusion that it was doubtful whether the organization of an investigation of the general properties of mineral aggregates of all kinds and for all purposes would be feasible or helpful at the present time. It has seemed to the committee that a study of the properties of mineral aggregates as used in various types of construction in which the Society is interested at present, such as roads, concrete structures, etc., is highly desirable. Such studies are being made by several committees of the Society, to some extent in cooperation, and consideration is being given to the possibility of still further coordinating and extending these studies. The committee understands the Papers Committee is planning for a general discussion of properties of mineral aggregates at the annual meeting next year, and there are several important contributions on this years' program.

Weathering Characteristics of Building Materials.—Several committees of the Society have become interested in studying the weathering characteristics of various types of building materials. The subject is one of considerable importance from the viewpoint of life and service of these materials and Committee E-9 is discussing the matter with the interested standing committees to see what steps may be taken by these committees in a concerted way to further our knowledge in this direction.

Comment on General Status of Research Work in the A.S.T.M.:

The research activities of the Society seem to be in a general state of healthy activity. Two outstanding facts are: (1) the long time required to bring any worth-while piece of research work to full fruition, and (2) the intimate intertwining of research problems and standardization problems in the work of many of our standing committees. While it is to be hoped that there will be organized many more purely research committees in the Society, it seems evident that a large part, perhaps the greater part, of the research work of the Society will always be done in connection with the work of the regular standing committees.

Respectfully submitted on behalf of the committee,

H. F. MOORE,
Chairman.

C. L. WARWICK,
Ex-Officio Secretary.

APPENDIX

LIST OF A.S.T.M. RESEARCH PROJECTS

There is given below a list of A.S.T.M. research projects under the following classifications:

1. Projects administered by A.S.T.M. standing committees;
2. Projects administered by A.S.T.M. research committees;
3. Projects administered by joint committees sponsored by the Society.

In general, this list records projects as of the date of the annual meeting of the Society in 1927 and does not include projects that may have been initiated by the standing committees since that meeting.

The projects are listed by brief title and index classification and in most instances there are given brief statements of the scopes of the projects. A more complete statement of the scope of each project, the manner of its administration and its present status is on file at the headquarters of the Society and information relating thereto will gladly be furnished to any committee or member of the Society upon request.

The standing committees of the Society whose names do not appear in the list fall in two classes: first, those whose activities have not involved any research in materials; and second, those that are devoting their major attention to methods of testing, in connection with which they are conducting many investigations (some of considerable magnitude) but which are not intended primarily to promote knowledge of the materials with which the committees are working and do not lend themselves to listing as specific projects. Information regarding the investigative work of such committees is, however, included in the files in the Secretary-Treasurer's office and is available for consultation.

PROJECTS ADMINISTERED BY A.S.T.M. STANDING COMMITTEES

Committee A-1 on Steel:

S 1. Concrete Reinforcement Bars (jointly with Committee C-2).

Investigation of the physical properties of concrete reinforcement bars, plain, deformed and twisted, rolled from four different grades of steel now in commercial use, in the form as rolled and in machined test specimens;

also an investigation of the efficiency of deformed bars when used as reinforcing in concrete, with special reference to the effect of the design of the bar on its bond resistance.

S 2. Effect on Properties of Forgings of Amount of Reduction Between Ingot and Bloom.

Effect on properties of forgings of amount of reduction between ingot and bloom. Includes tests of blooms with reductions from the ingot of two to one, three to one and four to one, both without treatment and annealed; also tests of rounds of several diameters, both pressed and hammered from billets made from the blooms.

S 42. Study of Single *versus* Double Welding of Lap-Welded Steel Pipe.

A study of the relative efficiency and economy of single *versus* double welded pipe for flanging. The results of this investigation will have a direct bearing on specification requirements.

Project completed. For final report see *Proceedings* Am. Soc. Testing Mats., Vol. 27, Part I, p. 115 (1927).

S 44. Size and Location of Test Coupon in Steel Castings.

To study size and location of coupons in steel castings.

Project completed. For final report see *Proceedings* Am. Soc. Testing Mats., Vol. 27, Part I, p. 114 (1927).

Committee A-2 on Wrought Iron:

S 3. Quality of Wrought Iron as Influenced by Manufacture and Heat Treatment.

Quality of wrought iron as influenced by manufacture and heat treatment. It is particularly contemplated to study the influence of raw material and processes of manufacture on puddled wrought iron.

S 4. Annealing of Wrought-Iron Chain (jointly with Committee A-4).

Effect of heat treatment of wrought iron in special cases, such as chain and other articles where the metal has been brought to a high temperature for welding; including the desirability of annealing iron chain at intervals; also red shortness of wrought iron when subjected to mechanical work at temperatures around 1500° F.

Committee A-3 on Cast Iron:

S 5. Arbitration Test Bar for Cast Iron.

Study of test bars for cast-iron from an international viewpoint. The object is to provide means of testing cast-iron products for export only, and no interference with the customs of the industry in the several countries is urged or contemplated.

Committee A-4 on Heat Treatment of Iron and Steel:

S 4. Annealing of Wrought-Iron Chain (jointly with Committee A-2).

Committee A-5 on Corrosion of Iron and Steel:

S 6. Atmospheric Corrosion Tests of Uncoated Sheets.

Exposure tests of bare (uncoated) steel and iron sheets under atmospheric conditions at Pittsburgh, Fort Sheridan and Annapolis.

S 7. Total Immersion Tests of Uncoated Sheets.

Tests of bare (uncoated) steel and iron sheets totally immersed in acid mine water at Calumet, Pa., in saline water at Annapolis, in city water at Washington. Also tests in open ocean water to determine the effect of corrosion on steel ship plate with and without copper when riveted with rivets of iron and steel with varying copper contents.

S 8. Atmospheric Corrosion Tests of Metallic Coated Products.

Comprehensive field tests at several locations representing varying atmospheric conditions on metal products coated by various processes, *e.g.*, hot-dipped galvanized sheets, wire products, structural shapes and castings; sherardized castings; electrozinc-plated castings; zinc-coated sprayed castings and structural shapes; terne-coated sheets; lead-coated sheets; cadmium-plated castings; and calorized castings. An important purpose of the tests is to correlate results of service with various types of laboratory, including accelerated, tests.

S 9. Accelerated Corrosion Tests.

Study of various methods of accelerated corrosion tests with particular reference to their application to metallic coated products. Related to the atmospheric exposure tests mentioned in S 6 and S 8. The main purpose is to find some tests which will give results indicative of what really occurs in service.

S 50. Metal Culvert Corrosion Tests.

A study of the corrosion of corrugated flexible metal culvert—in the beginning from a service standpoint as a material and not as a structure. Later it is planned to determine the suitability and comparative value of the different types of base metals used in flexible culvert construction and under varying soil and other conditions.

Limited for the present to corrugated flexible metal culvert, having in mind that later on the study of cast-iron culvert might be taken up.

Committee A-8 on Magnetic Analysis:

S 10. Study of Magnetic Properties of Steel and Their Correlation with Other Properties and with General Performance.

Study of magnetic properties of steel and their correlation with other properties and with general performance. This expresses briefly the aim of the committee in all of its work.

Committee B-2 on Non-Ferrous Metals and Alloys:

S 11. Test Bars for Cast Non-Ferrous Alloys.

A study of the best type of test bars for various cast non-ferrous alloys. The relationship between properties of the test bars and properties of the metal in the castings they represent is involved in this project.

S 12. General Study of Properties of Babbitt Metal.

This project includes determination of physical properties of white metal bearing alloys in the A.S.T.M. tentative standards; correct pouring temperatures of Babbitt metal; effect of ratio of length to diameter in compression testing of Babbitt metal; and effect of impurities on the properties of Babbitt metal, such as friction and wearing properties, fluidity, brittleness, and amount of drossing.

S 58. Investigation of Die-Casting Alloys.

An extensive investigation of die-casting alloys as to composition, strength, hardness, brittleness and resistance to corrosion. 50,000 specimens of various aluminum-base alloys and 25,000 specimens of zinc-base alloys are now being tested. The investigation will supply dependable information on the properties of alloys suitable for die-castings and will probably lead to the formulation of specifications based either on the alloys tested or on alloys developed as a result of the investigation.

Committee B-3 on Corrosion of Non-Ferrous Metals and Alloys:

S 13. Standardization of the Practice of Corrosion-Resistance Testing.

A study of four corrosion tests, namely, total immersion, alternate immersion, spray, and accelerated electrolytic. Six non-ferrous metals will be tested by a number of cooperating laboratories each following carefully prescribed methods and reporting data on standardized forms.

S 45. Atmospheric Corrosion of Non-Ferrous Metals and Alloys.

Atmospheric corrosion tests of a variety of non-ferrous metals and alloys in the form of rolled sheet or strip 0.035 in. thick.

S 46. Corrosion of Non-Ferrous Metals and Alloys in Liquids—Field Tests.

Testing in the field of the corrosion of metals in several common solutions under conditions representative of those existing in some industrial process which is in general use. (The metals to be included will be limited to those which may reasonably be expected to prove practicable for use in each process.) Four solutions planned are sodium hydroxide, hydrochloric acid, sodium chloride and sulfuric acid.

S 47. Galvanic and Electrolytic Corrosion of Non-Ferrous Metals and Alloys.

Study of galvanic effects (that is effect of contact between dissimilar metals upon the rate of corrosion of each) and electrolytic action in three liquid media of high, medium and low conductivity.

Committee B-4 on Metallic Materials for Electrical Heating:

S 48. Growth of Nickel-Chromium Resistor Materials Due to Continued and Repeated Heating.

Study of growth of nickel-chromium resistor materials due to continued and repeated heating in order to determine whether the phenomenon commonly described as growth is such in the true sense of the word or is the result of plastic flow of the metal at high temperature.

S 49. Life Test for Durability of Electrical Resistance Wire at High Temperatures.

To arrive at the best methods for determining the durability of resistance wire at high temperatures with due regard to service conditions.

Committee C-1 on Cement:

S 14. Compressive Strength Test of Cement Mortars.

Development of satisfactory commercial test for compressive strength of portland-cement mortars. Specification requirements are involved.

S 15. Development of Shorter Time Strength Test.

Consideration of suggestion that a three-day or four-day mortar strength test be developed for portland cement.

S 16. Sulfuric Anhydride and Magnesia Content of Cement.

Consideration of proposed changes in requirements for sulfuric anhydride and magnesia in portland cement.

S 43. Fluid Cement-Water Mixtures.

This project includes (1) tension and compression tests of fluid portland cement-water mixtures, including day-to-day uniformity of strength test, effect of varying quantity of mixing water and study of flow cylinder test for consistency of fluid cement-water mixtures; and (2) a study of the possibilities of a one or three-day strength test for portland cement.

Committee C-2 on Reinforced Concrete:

S 1. Concrete Reinforcement Bars (jointly with Committee A-1).

Committee C-3 on Brick:

S 18. Study of Test for Compressive Strength of Brick.

S 19. Present Condition of Bricks in Old Buildings.

To obtain, record and correlate information about the present condition of bricks in old buildings.

Committee C-4 on Clay and Cement-Concrete Pipe:

S 20. Chemical Test Requirements for Sewer Pipe.

To determine resistance of clay and cement-concrete sewer pipe to chemical actions. (The problem is being approached largely from the point of view of specification requirements.)

Committee C-6 on Drain Tile:

S 21. Chemical Test Requirements for Drain Tile.

Development of chemical tests and chemical test requirements for drain tile to determine their resistance to the action of alkalies and acids in the soil. (In cooperation with other organizations.)

Committee C-7 on Lime:

S 22. Cause of Plasticity.

A general investigation of the property of plasticity as relates to lime and lime products. Includes a study of relation between plasticity of lime-sand mortar and sand-carrying capacity of lime.

Committee C-9 on Concrete and Concrete Aggregates:

S 23. Design of Concrete.

Analyzing the existing data on various theories of proportioning concrete mixtures, and of developing an adequate theory of design.

S 36. Field Tests of Concrete.

Standardization of methods of making field specimens, including sampling of the concrete when soft, the methods of sampling hardened concrete, and the development of field tests for concrete. Investigation of the relations that may exist between the strengths of test specimens of different forms and dimensions. Relation between the compressive strength of test cylinders made in accordance with the A.S.T.M. standard method and prisms removed from slabs of the same mix.

S 37. Available Aggregates for Concrete.

S 38. Deleterious Substances in Concrete.

A study of the various naturally or accidentally occurring materials in concrete which may affect it deleteriously.

S 39. Admixtures.

A general study of admixtures which may be added to concrete for the purpose of improving some of its properties.

S 40. Conditions Affecting Durability of Concrete in Structures.

Study of the conditions under which concrete has not been durable. It will emphasize the precautions which must be taken to produce good concrete, whether in methods, materials or workmanship.

S 41. Elastic Properties of Concrete.

Studies of the elastic properties of concretes of different mixtures at different ages under different conditions of moisture, the effect of different aggregates, a determination of the modulus of elasticity of concrete in tension, establishment of Poisson's ratio, and establishment of the effect of brief application of loads including loads applied suddenly or with impact; also studies of the form of specimens, type of bearing, rate of application of load, sensitivity of measuring devices, etc.

Committee D-1 on Preservative Coatings for Structural Materials:

S 24. Paint Vehicles.

General studies of properties and methods of tests of paint vehicles, such as linseed oil, tung oil, soya bean oil, etc.

S 25. Varnish.

General studies of properties and methods of tests of varnish.

S 26. Turpentine and Other Paint Thinners.

General studies of properties and methods of tests of turpentine and other paint thinners.

S 27. Shellac.

General studies of properties and methods of tests of shellac and shellac varnish. Most of the sub-committee's work is expected to lead to standard specifications and methods of test.

S 28. Preparation of Iron and Steel Surfaces for Painting.

Study of influence of various methods of preparing iron and steel surfaces upon the life of painted sheets, under atmospheric exposure.

S 29. Anti-Corrosive and Anti-Fouling Paints.

Study of the value of various anti-corrosive and anti-fouling paints.

S 30. Physical Properties of Paint Materials.

A study of the physical problems connected with paints and paint materials. Viscosity and plasticity of paints and color and optical properties of paints and paint materials have first been considered.

Committee D-11 on Rubber Products:

S 54. Abrasion Tests of Rubber Products.

A test being developed for the general application to those rubber products where abrasion in service is the most important element in determining the life of the material, such as conveyor belting, automobile tires, rubber-covered·air and water hose, rubber heels, etc.

S 55. Life Tests of Rubber Products.

Accelerated aging test of various types of rubber compound in comparison with natural aging of the same samples.

S 56. Flexing Tests of Rubber Products.

A study of accelerated flexing tests of rubber products, especially of rubber belting, under conditions involving the deteriorating influences encountered in actual service. The results are correlated with actual service experience.

S 57. Shock Absorption of Rubber Products.

Study, development and standardization of methods of test which are particularly suitable in the evaluation of rubber stocks for shackles, motor supports, bumpers and shock insulators.

Committee D-14 on Screen Wire Cloth:

S 32. Relative Life of Various Screen Wire Cloth.

To determine the relative life of the higher grade screen wire cloths when exposed to various atmospheric agencies, such as corrosion and wind, as they exist in different localities and climates, so that purchasers of such material may make an economic selection best suited to their particular conditions.

Committee D-16 on Slate:

S 51. Abrasive Hardness of Slate.

To determine the wearing qualities of slate when used in floors, treads, etc.

S 52. Weathering Characteristics of Slate.

General study of the weathering characteristics of slate including both accelerated weathering test and observation of behavior under atmospheric conditions. Includes also study of chemical content of different slate and effect of acid on those slates.

S 53. Investigation of Sand Used for Rubbing Slate.

Investigation of the sand used for rubbing slate to increase efficiency and economies by the careful selection of sand.

Committee E-4 on Metallography:

S 33. Thermal Analysis of Metals.

Study of thermal analysis of metals, including standard methods.

S 34. Study of Micro-Hardness.

A study of methods for obtaining "scratch" or "scoring" hardness making use of a special instrument designed for this purpose.

Project completed. For final report see *Proceedings* Am. Soc. Testing Mats., Vol. 26, Part I, p. 572 (1926).

S 35. X-Ray Metallography.

A study of the applications of the X-ray (1) in the location of cavities, cracks and other structural variations in metals (Metal Radiography) and (2) to determine the arrangement of atoms or molecules in crystals, size of grain in crystallin aggregates and the orientation of such crystallin material (X-ray Crystallography).

PROJECTS ADMINISTERED BY A.S.T.M. RESEARCH COMMITTEES

R 1. Effect of Arsenic and Tin upon High-Speed Tool Steels.

Substantially as stated by title. The special committee wishes to determine the effect of tin and arsenic in a martensitic structure such as occurs in hardened high-speed steel.

R 2. Yield Point of Structural Steel.

The committee has decided that it will consider (*a*) what is the significance to the engineer of the yield point when determined accurately; (*b*) what is the range in yield point of structural steel (that is, low-carbon, medium-carbon, silicon and nickel steels), due to a numger of important factors, when furnished under specifications; (*c*) what testing procedure will insure sufficiently accurate determination of the yield point at minimum expense.

The work under group (*c*) is to be taken up first.

PROJECTS ADMINISTERED BY JOINT COMMITTEES SPONSORED BY THE SOCIETY

J 1. Effect of Temperature upon the Properties of Metals. Joint committee of A.S.T.M. and A.S.M.E.

J 2. Effect of Phosphorus and Sulfur in Steel. Joint committee under the auspices of eleven organizations.

J 3. Concrete Culvert Pipe. Joint committee under the auspices of seven organizations.

J 4. Concrete and Reinforced Concrete. Joint committee under the auspices of five organizations.

J 5. Sectional Committee on Specifications for Cast-Iron Pipe. Sectional committee under the auspices of the American Engineering Standards Committee, sponsored by four organizations.

J 6. Inclusions in Forgings. Joint committee of A.S.T.M. and A.R.A.

In addition to the above research projects under the sole or joint auspices of the Society, the Society is represented upon the following projects under other auspices:

O 1. Molding Sand Research.
O 2. Research on Metal Springs.
O 3. Research on Rock Drill Steels.
O 4. Research on Gage Steel.
O 5. Highway Research.
O 6. Pattern Equipment Standardization.
O 7. Corrosion Committee, American Society of Refrigerating Engineers.
O 9. Welding.
O 10. Investigation of Effect of Annealing on Chain.
O 11. Joint Committee on Boiler Feed Water Studies.
O 12. Joint Research Committee on Welding of Pressure Vessels.

The Society is also officially represented on the Division of Engineering and Industrial Research of the National Research Council.

A.S.T.M.
TENTATIVE STANDARDS

SUBMITTED OR REVISED
AT THE
1928 ANNUAL MEETING

The term Tentative Standard is applied to a proposed Standard which is printed for one or more years with a view of eliciting criticism, of which the committee concerned will take due cognizance before recommending final action towards its adoption as standard.

Members of the Society and others are invited to direct written criticisms of any of these Tentative Standards to the officer of the appropriate committee, whose name and address appear in the footnote to the title of each Tentative Standard.

TENTATIVE SPECIFICATIONS

FOR

IRON AND STEEL CHAIN[1]

Serial Designation: A 56 - 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1928.

Scope. 1. These specifications cover two classes of iron and steel chain generally used for the following purposes:

Crane Chain, for slings, hoists, steam shovels, and marine uses, and where an all-iron chain is desired.

Proof Coil, for railroad cars, construction and forestry work.

MANUFACTURE

Material. 2. The material entering into the two classes of chain shall be as follows:

Crane Chain.—Wrought iron which shall be made from all pig puddled iron free from any admixture of iron scrap or steel.

NOTE.—The term "iron scrap" applies only to foreign or bought scrap and does not include local mill products of crane chain iron quality.

Proof Coil.—Wrought iron or open-hearth steel. The wrought iron may be made from all reworked scrap.

NOTE.—The term "reworked scrap" applies to steel and iron scrap, or a mixture of both.

Welding. 3. Crane chain shall be lap fire-welded. Unless otherwise specified, Proof Coil chain may be made by either the fire or electric-welding process.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. G. H. Woodroffe, Secretary of Committee A-2 on Wrought Iron, Reading Iron Co., Reading, Pa.

These specifications, when adopted as standard, will supersede the present Standard Specifications for Iron and Steel Chain (Serial Designation: A 56 - 24), 1927 Book of A.S.T.M. Standards, Part I, p. 404.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition. 4. The wrought iron and steel of the respective classes of chain shall conform to the following requirements as to chemical composition:

	Wrought Iron Crane Chain	Steel Proof Coil
Manganese, maximum, per cent	0.10	....
Phosphorus, " "	....	0.04
Sulfur, " "	....	0.04

Check Analyses. 5. (*a*) Analyses may be made by the purchaser from the bars or from the finished chain. The chemical composition thus determined shall conform to the requirements specified in Section 4.

(*b*) Samples for analysis shall be taken with a drill the diameter of which is approximately one-half the diameter of the bar from which the drillings are taken, and the borings shall be taken through the bar from surface to surface.

PHYSICAL PROPERTIES AND TESTS

Proof Tests. 6. (*a*) All chain shall be proof tested by subjecting it to the proof test load, shown in Table I, for the respective size chain, and when so tested it shall stand these loads without showing any defects.

(*b*) When requested, the manufacturer shall furnish a certificate of proof test to the purchaser or his representative.

Break Tests. 7. (*a*) Test specimens from the finished chain shall conform to the minimum requirements for the break test loads specified in Table I.

Test Specimens. (*b*) Test specimens shall consist of a length not less than 2 ft. cut from the finished chain.

Number of Tests. (*c*) One break test shall be made to represent each lot of 200 ft. of chain or fraction thereof ordered.

Retests. 8. If the test specimen fails to conform to the requirements specified in Section 7 (*a*), two additional test specimens from the same lot may be tested, each of which shall conform to the requirements of Section 7(*a*).

Elongation. 9. The elongation, determined in a gage length of from 12 to 18 in. to the nearest link, shall not be less than 15 per cent for both Crane and Proof Coil chain.

Etch Tests. 10. *Crane Chain.*—The cross-section of the test specimen shall be ground or polished, and etched[1] for a sufficient period to develop the structure. The test shall show the material to be free from steel.

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[1] A solution of 10 per cent hydrochloric acid (sp. gr. 1.19), 30 per cent sulfuric acid (sp. gr. 1.84), and 60 per cent water; or 25 per cent nitric acid (sp. gr. 1.42) and 75 per cent water, is recommended for the etch test.

TABLE I.—PROOF AND BREAK TEST LOADS.

Nominal Size of Chain Bar, in.	Proof Test Load, lb.		Break Test Load, lb.		Safe Working Load, lb.	
	Crane Chain Wrought Iron	Proof Coil Iron or Steel	Crane Chain Wrought Iron	Proof Coil Iron or Steel	Crane Chain Wrought Iron	Proof Coil Iron or Steel
$\frac{1}{4}$	1 767	1 700	3 535	3 400	1 060	850
$\frac{5}{16}$	2 760	2 650	5 520	5 300	1 655	1 325
$\frac{3}{8}$	3 975	3 850	7 950	7 700	2 385	1 925
$\frac{7}{16}$	5 415	5 250	10 830	10 500	3 250	2 625
$\frac{1}{2}$	7 072	6 850	14 145	13 700	4 240	3 425
$\frac{9}{16}$	8 947	8 650	17 895	17 300	5 370	4 325
$\frac{5}{8}$	11 047	10 700	22 095	21 400	6 630	5 350
$\frac{3}{4}$	15 900	15 350	31 800	30 700	9 540	7 675
$\frac{7}{8}$	21 622	20 900	43 245	41 800	12 960	10 450
1	28 275	27 350	56 550	54 700	16 950	13 675
$1\frac{1}{8}$	33 400	....	66 800	....	20 040	....
$1\frac{1}{4}$	41 250	....	82 500	....	24 750	....
$1\frac{3}{8}$	49 900	....	99 800	....	29 910	....
$1\frac{1}{2}$	59 350	....	118 700	....	35 600	....
$1\frac{5}{8}$	69 750	....	139 500	....	41 800	....
$1\frac{3}{4}$	80 800	....	161 600	....	48 450	....
$1\frac{7}{8}$	92 750	....	185 500	....	55 300	....
2	105 500	....	211 100	....	63 300	....

TABLE II.—NOMINAL WEIGHTS AND DIMENSIONS.

Nominal Size of Chain Bar, in.	Actual Size of Material, in.	Nominal Length of 100 Links, in.		Nominal Weight per 100 ft., lb.		Nominal Dimensions of Links, in.							
						Crane Chain				Proof Coil			
						Outside		Inside		Outside		Inside	
		Crane Chain	Proof Coil	Crane Chain	Proof Coil	Length	Width	Length	Width	Length	Width	Length	Width
$\frac{1}{4}$	$\frac{9}{32}$	86	100	78	70	$1\frac{27}{64}$	1	$\frac{55}{64}$	$\frac{7}{16}$	$1\frac{9}{16}$	$1\frac{1}{16}$	1	$\frac{1}{2}$
$\frac{5}{16}$	$\frac{11}{32}$	100	111	115	105	$1\frac{11}{16}$	$1\frac{3}{16}$	1	$\frac{1}{2}$	$1\frac{51}{64}$	$1\frac{3}{16}$	$1\frac{7}{64}$	$\frac{1}{2}$
$\frac{3}{8}$	$\frac{13}{32}$	109	123	166	158	$1\frac{29}{32}$	$1\frac{7}{16}$	$1\frac{3}{32}$	$\frac{5}{8}$	$2\frac{3}{64}$	$1\frac{7}{16}$	$1\frac{15}{64}$	$\frac{5}{8}$
$\frac{7}{16}$	$\frac{15}{32}$	122	138	220	210	$2\frac{5}{32}$	$1\frac{5}{8}$	$1\frac{7}{32}$	$\frac{11}{16}$	$2\frac{5}{16}$	$1\frac{11}{16}$	$1\frac{3}{8}$	$\frac{3}{4}$
$\frac{1}{2}$	$\frac{17}{32}$	134	150	275	265	$2\frac{13}{32}$	$1\frac{13}{16}$	$1\frac{11}{32}$	$\frac{3}{4}$	$2\frac{9}{16}$	$1\frac{7}{8}$	$1\frac{1}{2}$	$\frac{13}{16}$
$\frac{9}{16}$	$\frac{19}{32}$	156	175	350	335	$2\frac{3}{4}$	$1\frac{15}{16}$	$1\frac{9}{16}$	$\frac{3}{4}$	$2\frac{15}{16}$	$2\frac{1}{16}$	$1\frac{3}{4}$	$\frac{7}{8}$
$\frac{5}{8}$	$\frac{21}{32}$	169	188	430	410	3	$2\frac{3}{16}$	$1\frac{11}{16}$	$\frac{7}{8}$	$3\frac{3}{16}$	$2\frac{5}{16}$	$1\frac{7}{8}$	1
$\frac{3}{4}$	$\frac{25}{32}$	188	213	615	580	$3\frac{7}{16}$	$2\frac{9}{16}$	$1\frac{7}{8}$	1	$3\frac{11}{16}$	$2\frac{11}{16}$	$2\frac{1}{8}$	$1\frac{1}{8}$
$\frac{7}{8}$	$\frac{29}{32}$	225	250	820	780	$4\frac{1}{16}$	$3\frac{1}{16}$	$2\frac{1}{4}$	$1\frac{1}{4}$	$4\frac{5}{16}$	$3\frac{3}{16}$	$2\frac{1}{2}$	$1\frac{3}{8}$
1	$1\frac{1}{32}$	256	275	1045	1000	$4\frac{5}{8}$	$3\frac{7}{16}$	$2\frac{9}{16}$	$1\frac{3}{8}$	$4\frac{13}{16}$	$3\frac{9}{16}$	$2\frac{3}{4}$	$1\frac{1}{2}$
$1\frac{1}{8}$	$1\frac{5}{32}$	288	...	1310	...	$5\frac{3}{16}$	$3\frac{15}{16}$	$2\frac{7}{8}$	$1\frac{5}{8}$	...	...	...	...
$1\frac{1}{4}$	$1\frac{9}{32}$	306	...	1600	...	$5\frac{5}{8}$	$4\frac{5}{16}$	$3\frac{1}{16}$	$1\frac{3}{4}$	...	...	...	...
$1\frac{3}{8}$	$1\frac{13}{32}$	363	...	1930	...	$6\frac{7}{16}$	$4\frac{11}{16}$	$3\frac{5}{8}$	$1\frac{7}{8}$	...	...	...	...
$1\frac{1}{2}$	$1\frac{17}{32}$	387	...	2335	...	$6\frac{15}{16}$	$5\frac{1}{16}$	$3\frac{7}{8}$	2	...	...	...	...
$1\frac{5}{8}$	$1\frac{21}{32}$	425	...	2740	...	$7\frac{9}{16}$	$5\frac{7}{16}$	$4\frac{1}{4}$	$2\frac{1}{8}$	...	...	...	...
$1\frac{3}{4}$	$1\frac{25}{32}$	475	...	3180	...	$8\frac{5}{16}$	$5\frac{13}{16}$	$4\frac{3}{4}$	$2\frac{1}{4}$	...	...	...	...
$1\frac{7}{8}$	$1\frac{29}{32}$	525	...	3650	...	$9\frac{1}{16}$	$6\frac{5}{16}$	$5\frac{1}{4}$	$2\frac{1}{2}$	...	...	...	...
2	$2\frac{1}{32}$	575	...	4100	...	$9\frac{13}{16}$	$6\frac{11}{16}$	$5\frac{3}{4}$	$2\frac{5}{8}$	...	...	...	...

STANDARD WEIGHTS AND DIMENSIONS

Nominal Weights and Lengths.

11. (*a*) The nominal length of 100 links, the nominal weight per 100 ft., and the nominal dimensions of links for chain of various sizes shall conform to those specified in Table II.

(*b*) The length of 100 links and the weight per 100 ft. of chain shall not vary more than 4 per cent over nor more than 4 per cent under the nominal weight and length specified in Table II for the respective size chain. Weight in excess of the permissible variation of 4 per cent over that specified may be cause for rejection. All chain accepted will be paid for according to actual weights.

Length.

12. (*a*) The length shall be determined by measuring to the inside of the end links and the determination shall be made after the chain has been subjected to the proof test.

(*b*) In determining the length of the chain, a load not exceeding 10 per cent of the proof test load specified in Table I shall be applied to take up the slack.

WORKMANSHIP AND FINISH

Workmanship and Finish.

13. (*a*) The chain shall be free from injurious defects and shall have a workmanlike finish. The diameter of the bar in all chain shall not be less than the nominal size in the body and welds, and, unless otherwise specified, the diameter of the weld shall not exceed the diameter of the bar by more than 25 per cent.

(*b*) Prior to testing and inspection the chain shall be free from paint or other coating which would tend to conceal defects.

INSPECTION AND REJECTION

Inspection.

14. (*a*) The inspector representing the purchaser shall have free entry at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the chain ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the chain is being furnished in accordance with these specifications.

(*b*) Unless otherwise specified, all tests and inspection shall be made at the place of manufacture; but when specified by the purchaser he may make the tests and inspection to govern the acceptance or rejection of the chain at his own laboratory or elsewhere at his own expense.

(*c*) All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

15. Unless otherwise specified, any rejection based on tests made in accordance with Section 14 (*b*) shall be reported within five working days from the receipt of specimens. **Rejection.**

16. Specimens tested in accordance with Section 14 (*b*), which represent rejected chain, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time. **Rehearing.**

TENTATIVE SPECIFICATIONS
FOR
ELECTRIC CAST-STEEL STUD-LINK ANCHOR CHAIN[1]

Serial Designation: A 77 – 28 T

This is a Tentative Standard, published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1918; REVISED, 1920, 1928.

Scope. 1. These specifications cover the cast steel to be used in all parts of the complete chain, including stud links, enlarged links, end links, swivels, shackles and shackle pins.

Basis of Purchase. 2. (*a*) The purchaser shall specify the general layout and location of each swivel, shackle or other appendage. No chain appendages, such as swivels, shackles or shackle pins, shall be furnished with any order of chain unless specifically called for, provided, however, that swivels in the outboard shots shall be furnished when outboard shots are specifically called for, and the required connecting shackles and shackle pins and anchor shackles and shackle pins shall be furnished when complete chain cables are ordered.

(*b*) Special requirements of the purchaser, such as change in design or additional tests, shall be specifically covered by the order or contract.

MANUFACTURE

Process. 3. (*a*) The steel shall be made by the electric-furnace process and shall be a homogeneous fine-grain cast steel.

(*b*) Each complete shot of chain, including swivels, shackles, shackle pins and other appendages, shall be heat treated in such a manner that the treatment will be complete and uniform throughout its entire length or section.

PHYSICAL PROPERTIES AND TESTS

Physical Properties and Tests. 4. Castings of all chain links, swivels, shackles, shackle pins and other appendages shall withstand the break test loads and proof test loads shown in Table I in accordance with the break and proof tests described in Sections 5 to 9 inclusive.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. V. H. Lawrence, Secretary of Committee A-1 on Steel, Alan Wood Iron and Steel Co., Conshohocken, Pa.

Break Tests.

5. (*a*) From each heat of steel entering into the production of any shot of chain, swivels, shackles, shackle pins and other appendages, there shall be cast not less than one link in each of two test chains. The links entering into these test chains shall be of the same wire diameter and general dimensions as the common "A" links, shown in Table II, that form a part of the shot or shots of chain they represent. Each of these test chains shall contain not less than three links. These test chains shall be heat treated along with any shot or shots of chain containing links poured from the same heat or heats.

(*b*) After heat treatment, one of the test chains shall be subjected to the break test by anchoring the ends of the test chain in an approved static testing machine and loading it to the break test load, shown in Table I, for the respective size chain. If this test chain withstands the required break test load, the second test chain may be incorporated and become a part of any subsequent shot of chain prior to heat treatment or reheat treatment of the shot of chain involved.

TABLE I.—PROOF AND BREAK TEST LOADS.

Size of Chain Cable, in.[a]	Proof Test Load, lb.	Break Test Load, lb.	Size of Chain Cable, in.[a]	Proof Test Load, lb.	Break Test Load, lb.
1	60 000	84 000	$2\frac{5}{8}$	385 440	539 620
$1\frac{1}{8}$	75 540	105 760	$2\frac{3}{4}$	420 660	588 930
$1\frac{1}{4}$	92 770	129 880	$2\frac{7}{8}$	457 190	640 070
$1\frac{3}{8}$	111 660	156 330	3	495 000	693 000
$1\frac{1}{2}$	132 190	185 060	$3\frac{1}{8}$	534 060	747 680
$1\frac{5}{8}$	154 310	216 030	$3\frac{1}{4}$	574 340	804 070
$1\frac{3}{4}$	178 000	249 210	$3\frac{3}{8}$	615 800	862 130
$1\frac{7}{8}$	203 250	284 540	$3\frac{1}{2}$	658 440	921 810
2	230 000	322 000	$3\frac{5}{8}$	702 200	983 080
$2\frac{1}{8}$	258 240	361 530	$3\frac{3}{4}$	747 070	1 045 900
$2\frac{1}{4}$	287 930	403 100	$3\frac{7}{8}$	793 010	1 110 210
$2\frac{3}{8}$	319 050	446 660	4	840 000	1 176 000
$2\frac{1}{2}$	351 560	492 190	$4\frac{1}{8}$	888 000	1 243 200

[a] For tests of "A," "B," and "E" links of outboard shot use figures for the next larger size cable.

(*c*) If the first test chain fails to withstand the break test load as described in Paragraph (*b*), then the second test chain representing the same heats of steel shall be subjected to the break test in accordance with Paragraph (*b*). Prior to the testing of the second test chain, the second test chain together with all chain products poured from the same heat or heats represented by the links in the test chains may be reheat treated, if in the opinion of the manufacturer such reheat treatment will improve the quality of the product. If any link or links in the second test chain fails during this test, then all chain products poured from the same heat or heats represented by the links that failed during both the first and second break tests shall be rejected, and, in the case of links in a shot of chain, they shall be cut out and new links cast in the shot or shots, replacing the rejected links.

Proof Tests.

6. (*a*) Any shot or shots of chain that have met the requirements of the break test described in Section 5, shall be subjected to the proof test. The ends of the shot or shots of chain shall be anchored in an approved static testing machine and subjected to the proof test load, shown in Table I, for the respective size chain.

(*b*) If any link or links fail during the proof test described in Paragraph (*a*), such link or links may be replaced by casting in a new link or links and the shot of chain reheat treated and again subjected to the proof test in accordance with Paragraph (*a*). The new link or links added shall be cast from a heat of steel from which representative test chains have met the requirements of the break test in accordance with Section 5. If any link or links in any shot of chain fail during this retest, then all chain products poured from the same heat or heats as those links which failed during the first and second proof test shall be rejected from that shot of chain. Any links not so rejected may be used in building a new shot of chain, provided such links have not passed through the heat treating process exceeding three times.

Outboard Swivel Shots of Chain:

Break Tests.

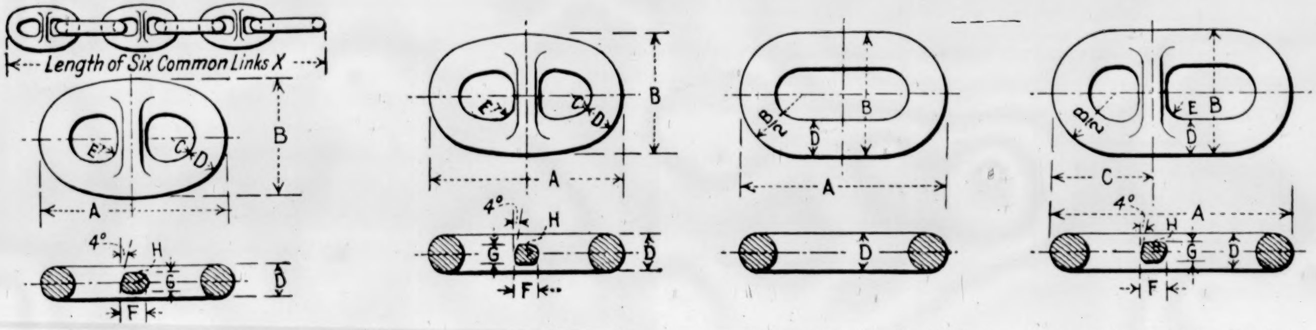
7. (*a*) *Break Tests.*—When outboard swivel shots of chain of a larger wire size are ordered or manufactured separately, the test chains representing the heats of steel poured into outboard swivel shots shall be composed of links having the same wire size and general dimensions as the common "A" links, shown in Table II, which form a part of the outboard swivel shots. These test chains shall be heat treated and subjected to the break test loads for chain of that wire size, shown in Table I, in accordance with and subject to the same provisions as specified for the break tests in Section 5.

(*b*) When outboard swivel shots of chain are ordered with other chain cable and in the process of manufacturing are poured from the same heats of steel that enter into the inboard shots of chain, one set of test chains may represent the heats of steel poured, and the links of such test chains shall be of the same wire size and general dimensions as the common "A" links, shown in Table II, of either the inboard

TABLE II.—DIMENSIONS OF COMMON, ENLARGED, AND END LINKS OF ELECTRIC CAST-STEEL ANCHOR CHAIN.

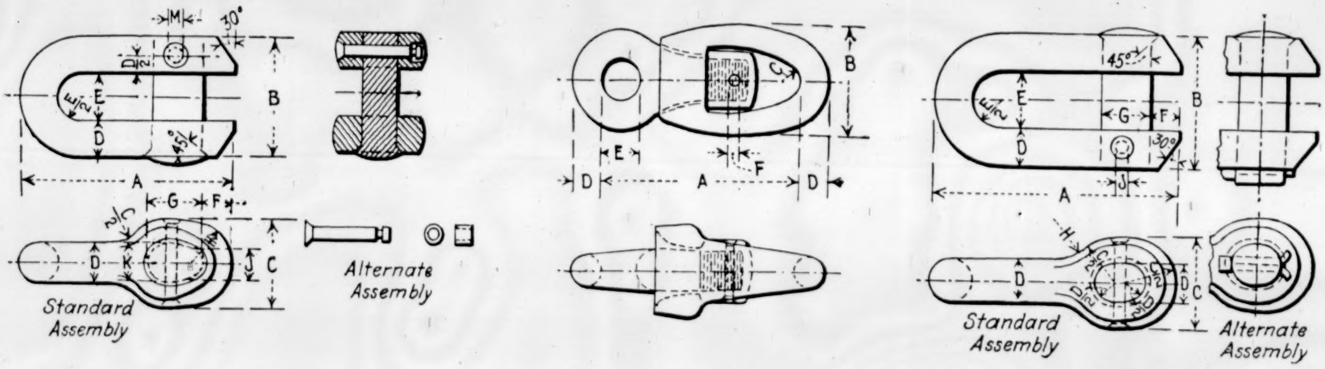
Size of Chain Cable, in	Common Links "A" [see Fig. 1 (*a*)]									Enlarged Links "B" [see Fig. 1 (*b*)]								End Links "E" [see Fig. 1 (*c*)]			End Links "C" [see Fig. 1 (*d*)]							
	A	B	C	D	E	F	G	H	X	A	B	C	D	E	F	G	H	A	B	D	A	B	C	D	E	F	G	H
1........	6	3 9/16	21/32	1	1/2	11/16	5/8	3/16	26	6 3/8	3 3/4	11/16	1 1/16	1/2	11/16	5/8	3/16	6 1/2	4	1 3/16	7 9/16	4	3 3/16	1 3/16	1/2	11/16	5/8	1/4
1 1/8........	6 3/4	4	23/32	1 1/8	9/16	3/4	11/16	3/16	29 1/4	7 3/16	4 1/4	3/4	1 3/16	9/16	3/4	11/16	3/16	7 5/16	4 1/2	1 5/16	8 1/2	4 1/2	3 9/16	1 5/16	9/16	3/4	11/16	1/4
1 1/4........	7 1/2	4 1/2	25/32	1 1/4	5/8	7/8	3/4	3/16	32 1/2	7 15/16	4 3/4	13/16	1 5/16	5/8	7/8	3/4	3/16	8 1/8	5	1 1/2	9 7/16	5	3 15/16	1 1/2	5/8	7/8	3/4	1/4
1 3/8........	8 1/4	4 15/16	7/8	1 3/8	11/16	15/16	13/16	1/4	35 3/4	8 3/4	5 3/16	15/16	1 7/16	11/16	15/16	13/16	1/4	8 15/16	5 1/2	1 5/8	10 3/8	5 1/2	4 3/8	1 5/8	11/16	15/16	13/16	1/4
1 1/2........	9	5 3/8	15/16	1 1/2	3/4	1	7/8	1/4	39	9 9/16	5 11/16	1	1 9/16	3/4	1	7/8	1/4	9 13/16	6	1 13/16	11 5/16	6	4 11/16	1 13/16	3/4	1	7/8	1/4
1 5/8........	9 3/4	5 7/8	1	1 5/8	13/16	1 1/8	15/16	1/4	42 1/4	10 3/8	6 1/8	1 1/16	1 3/4	13/16	1 1/8	15/16	1/4	10 9/16	6 1/2	1 15/16	12 1/4	6 1/2	5 1/8	1 15/16	13/16	1 1/8	15/16	1/4
1 3/4........	10 1/2	6 5/16	1 1/16	1 3/4	7/8	1 3/16	1	1/4	45 1/2	11 1/8	6 5/8	1 1/8	1 7/8	7/8	1 3/16	1	1/4	11 3/8	7	2 1/16	13 3/16	7	5 9/16	2 1/16	7/8	1 3/16	1	1/4
1 7/8........	11 1/4	6 3/4	1 1/8	1 7/8	15/16	1 1/4	1 1/8	1/4	48 3/4	11 15/16	7 1/16	1 1/4	2	15/16	1 1/4	1 1/8	1/4	12 1/4	7 1/2	2 1/4	14 1/8	7 1/2	5 7/8	2 1/4	15/16	1 1/4	1 1/8	1/4
2........	12	7 3/16	1 1/4	2	1	1 3/8	1 3/16	1/4	52	12 3/4	7 9/16	1 5/16	2 1/8	1	1 3/8	1 3/16	1/4	13 1/16	8	2 3/8	15 1/16	8	6 5/16	2 3/8	1	1 3/8	1 3/16	1/4
2 1/8........	12 3/4	7 5/8	1 5/16	2 1/8	1 1/16	1 7/16	1 1/4	1/4	55 1/4	13 1/2	8	1 3/8	2 1/4	1 1/16	1 7/16	1 1/4	1/4	13 7/8	8 1/2	2 1/2	16	8 1/2	6 3/4	2 1/2	1 1/16	1 7/16	1 1/4	1/4
2 1/4........	13 1/2	8 1/8	1 3/8	2 1/4	1 1/8	1 1/2	1 3/8	1/4	58 1/2	14 3/8	8 1/2	1 7/16	2 3/8	1 1/8	1 1/2	1 3/8	1/4	14 11/16	9	2 11/16	16 15/16	9	7 1/16	2 11/16	1 1/8	1 1/2	1 3/8	1/4
2 3/8........	14 1/4	8 9/16	1 7/16	2 3/8	1 3/16	1 5/8	1 7/16	1/4	61 3/4	15 3/16	9	1 1/2	2 1/2	1 3/16	1 5/8	1 7/16	1/4	15 1/2	9 1/2	2 13/16	17 7/8	9 1/2	7 3/8	2 13/16	1 3/16	1 5/8	1 7/16	1/4
2 1/2........	15	9	1 1/2	2 1/2	1 1/4	1 11/16	1 1/2	1/4	65	15 15/16	9 7/16	1 9/16	2 5/8	1 1/4	1 11/16	1 1/2	1/4	16 1/4	10	3	18 7/8	10	7 7/8	3	1 1/4	1 11/16	1 1/2	1/4
2 5/8........	15 3/4	9 7/16	1 9/16	2 5/8	1 5/16	1 13/16	1 9/16	1/4	68 1/4	16 3/4	9 15/16	1 5/8	2 13/16	1 5/16	1 13/16	1 9/16	1/4	17 1/8	10 1/2	3 1/8	19 3/4	10 1/2	8 5/16	3 1/8	1 5/16	1 13/16	1 9/16	1/4
2 3/4........	16 1/2	9 7/8	1 5/8	2 3/4	1 3/8	1 7/8	1 5/8	1/4	71 1/2	17 9/16	10 3/8	1 11/16	2 15/16	1 3/8	1 7/8	1 5/8	1/4	17 15/16	11	3 1/4	20 3/4	11	8 11/16	3 1/4	1 3/8	1 7/8	1 5/8	1/4
2 7/8........	17 1/4	10 3/8	1 11/16	2 7/8	1 7/16	1 15/16	1 3/4	1/4	74 3/4	18 5/16	10 7/8	1 13/16	3 1/16	1 7/16	1 15/16	1 3/4	1/4	18 3/4	11 1/2	3 7/16	21 11/16	11 1/2	9 1/16	3 7/16	1 7/16	1 15/16	1 3/4	1/4
3........	18	10 13/16	1 13/16	3	1 1/2	2 1/16	1 13/16	1/4	78	19 1/8	11 3/8	1 7/8	3 3/16	1 1/2	2 1/16	1 13/16	1/4	19 9/16	12	3 9/16	22 5/8	12	9 1/2	3 9/16	1 1/2	2 1/16	1 13/16	1/4
3 1/8........	18 3/4	11 1/4	1 7/8	3 1/8	1 9/16	2 1/8	1 7/8	1/4	81 1/4	19 15/16	11 13/16	1 15/16	3 5/16	1 9/16	2 1/8	1 7/8	1/4	20 7/16	12 1/2	3 11/16	23 9/16	12 1/2	9 7/8	3 11/16	1 9/16	2 1/8	1 7/8	1/4
3 1/4........	19 1/2	11 11/16	1 15/16	3 1/4	1 5/8	2 3/16	1 15/16	1/4	84 1/2	20 3/4	12 1/4	2	3 7/16	1 5/8	2 3/16	1 15/16	1/4	21 3/16	13	3 7/8	24 1/2	13	10 1/4	3 7/8	1 5/8	2 3/16	1 15/16	1/4
3 3/8........	20 1/4	12 1/8	2	3 3/8	1 11/16	2 5/16	2	1/4	87 3/4	21 1/2	12 3/4	2 1/16	3 9/16	1 11/16	2 5/16	2	1/4	22	13 1/2	4	25 7/16	13 1/2	10 5/8	4	1 11/16	2 5/16	2	1/4
3 1/2........	21	12 5/8	2 1/16	3 1/2	1 3/4	2 3/8	2 1/8	1/4	91	22 5/16	13 1/4	2 1/8	3 3/4	1 3/4	2 3/8	2 1/8	1/4	22 13/16	14	4 3/16	26 3/8	14	11	4 3/16	1 3/4	2 3/8	2 1/8	1/4
3 5/8........	21 3/4	13 1/16	2 1/8	3 5/8	1 13/16	2 7/16	2 3/16	1/4	94 1/4	23	13 11/16	2 3/16	3 7/8	1 13/16	2 7/16	2 3/16	1/4	23 5/8	14 1/2	4 5/16	27 5/16	14 1/2	11 7/16	4 5/16	1 13/16	2 7/16	2 3/16	1/4
3 3/4........	22 1/2	13 1/2	2 3/16	3 3/4	1 7/8	2 9/16	2 1/4	1/4	97 1/2	23 7/8	14 3/16	2 1/4	4	1 7/8	2 9/16	2 1/4	1/4	24 1/2	15	4 7/16	28 1/4	15	11 7/8	4 7/16	1 7/8	2 9/16	2 1/4	1/4
3 7/8........	23 1/4	13 15/16	2 1/4	3 7/8	1 15/16	2 5/8	2 5/16	1/4	100 3/4	24 11/16	14 11/16	2 5/16	4 1/8	1 15/16	2 5/8	2 5/16	1/4	25 1/4	15 1/2	4 5/8	29 5/16	15 1/2	12 3/16	4 5/8	1 15/16	2 5/8	2 5/16	1/4
4........	24	14 3/8	2 5/16	4	2	2 3/4	2 3/8	1/4	104	25 1/4	15 1/8	2 3/8	4 1/4	2	2 3/4	2 3/8	1/4	26	16	4 3/4	30 3/16	16	12 5/8	4 3/4	2	2 3/4	2 3/8	1/4
4 1/8........	24 3/4	14 13/16	2 3/8	4 1/8	2 1/16	2 13/16	2 1/2	1/4	107 1/4	26 5/16	15 5/8	2 7/16	4 3/8	2 1/16	2 13/16	2 1/2	1/4	26 7/8	16 1/2	4 15/16	31 3/16	16 1/2	13 1/16	4 7/8	2 1/16	2 13/16	2 1/2	1/4

NOTE.—The code of dimensioning used in this Table is shown in Fig. 1.


Length of Six Common Links X
A
B
C
D
E
F
G
H
4°
B/2

(*a*) Common Links "A." (*b*) Enlarged Links "B." (*c*) End Links "E." (*d*) End Links "C."

FIG. 1.—Code of Dimensioning of Chain Links to be Used with Table II.


M
30°
D/2
E/2
E
D
45°
B
A
G
F
C/2
K
J
C
Standard Assembly
Alternate Assembly
B
E
A
F
D
C
45°
G
F
30°
J
H
D/2
C/2
Standard Assembly
Alternate Assembly

(*a*) Shackles "D" and Shackle Pins. (*b*) Swivels. (*c*) Bending Shackles "F."

FIG. 2.—Code of Dimensioning of Shackles and Swivels to be Used with Table III.

TABLE III.—DIMENSIONS OF SWIVELS, SHACKLES, AND SHACKLE PINS OF ELECTRIC CAST-STEEL ANCHOR CHAIN.

Size of Chain Cable, in.	Shackles "D" and Shackle Pins [see Fig. 2 (a)]											Swivels [see Fig. 2 (b)]						Bending Shackles "F" and Shackle Pins [see Fig. 2 (c)								
	A	B	C	D	E	F	G	H	J	K	M	A	B	C	D	E	F	A	B	C	D	E	F	G	H	J
1	6 11/16	3 13/16	2 13/16	1 3/16	1 7/16	1	1 5/8	1 5/16	1	1 3/16	3/8	7 7/8	4 5/8	23/32	1 3/16	1 3/4	3/8	8 15/16	5 1/8	3 5/16	1 7/16	2	1 1/8	1 13/16	1 5/8	1/2
1 1/8	7 9/16	4 3/16	3 3/16	1 5/16	1 9/16	1 3/16	1 13/16	1 1/2	1 1/8	1 5/16	3/8	7 7/8	5 1/8	25/32	1 5/16	1 7/8	3/8	10 1/8	5 5/8	3 9/16	1 9/16	2 1/4	1 1/4	2	1 3/4	1/2
1 1/4	8 7/16	4 13/16	3 1/2	1 1/2	1 13/16	1 5/16	2	1 9/16	1 1/4	1 1/2	1/2	11 1/4	5 5/8	27/32	1 1/2	2 1/8	3/8	11 1/4	6 1/4	4	1 3/4	2 1/2	1 3/8	2 1/4	1 15/16	5/8
1 3/8	9 1/4	5 3/16	3 7/8	1 5/8	1 15/16	1 7/16	2 1/4	1 3/4	1 3/8	1 5/8	1/2	11 1/4	6 1/8	7/8	1 5/8	2 3/8	3/8	12 3/8	6 7/8	4 7/16	1 15/16	2 3/4	1 1/2	2 1/2	2 3/16	5/8
1 1/2	10 1/16	5 13/16	4 5/16	1 13/16	2 3/16	1 5/8	2 7/16	1 15/16	1 1/2	1 13/16	1/2	12 5/8	6 5/8	15/16	1 3/4	2 1/2	3/8	13 1/2	7 1/2	4 7/8	2 1/8	3	1 5/8	2 11/16	2 3/8	5/8
1 5/8	10 7/8	6 3/16	4 9/16	1 15/16	2 5/16	1 11/16	2 5/8	2 1/16	1 5/8	1 15/16	5/8	12 5/8	7 1/8	1	1 7/8	2 5/8	1/2	14 1/2	8	5 1/4	2 1/4	3 1/4	1 3/4	2 15/16	2 9/16	3/4
1 3/4	11 11/16	6 5/8	4 15/16	2 1/16	2 1/2	1 13/16	2 7/8	2 1/4	1 3/4	2 1/16	5/8	15	7 1/2	1 1/16	2	2 3/4	1/2	15 5/8	8 5/8	5 11/16	2 7/16	3 1/2	1 7/8	3 1/8	2 3/4	3/4
1 7/8	12 1/2	7 3/16	5 1/4	2 1/4	2 11/16	1 7/8	3 1/16	2 3/8	1 7/8	2 1/4	5/8	15	8	1 1/8	2 1/8	2 7/8	1/2	16 13/16	9 1/4	6	2 5/8	3 3/4	2	3 3/8	2 15/16	3/4
2	13 5/16	7 5/8	5 5/8	2 3/8	2 7/8	2	3 1/4	2 9/16	2	2 3/8	3/4	15	8 1/2	1 1/4	2 1/4	3 1/8	5/8	17 15/16	9 7/8	6 7/16	2 13/16	4	2 1/8	3 5/8	3 1/8	7/8
2 1/8	14 1/8	8	6	2 1/2	3	2 1/8	3 7/16	2 3/4	2 1/8	2 1/2	3/4	15	9	1 5/16	2 3/8	3 1/4	5/8	19 1/16	10 1/2	6 7/8	3	4 1/4	2 1/4	3 7/8	3 1/2	7/8
2 1/4	14 15/16	8 5/8	6 5/16	2 11/16	3 1/4	2 3/16	3 11/16	2 7/8	2 1/4	2 11/16	3/4	18 1/4	9 1/2	1 3/8	2 1/2	3 3/8	5/8	20 1/16	11	7 1/4	3 1/8	4 1/2	2 3/8	4 1/16	3 3/4	7/8
2 3/8	15 13/16	9	6 11/16	2 13/16	3 3/8	2 3/8	3 7/8	3 1/16	2 3/8	2 13/16	7/8	18 1/4	10	1 7/16	2 5/8	3 1/2	3/4	21 3/8	11 3/4	7 5/8	3 3/8	4 3/4	2 1/2	4 1/4	4	1
2 1/2	16 5/8	9 5/8	7 1/8	3	3 5/8	2 1/2	4 1/16	3 1/4	2 1/2	3	7/8	18 1/4	10 1/2	1 1/2	2 3/4	3 5/8	3/4	22 3/8	12 1/4	8	3 1/2	5	2 5/8	4 1/2	4 1/4	1
2 5/8	17 1/2	10	7 3/8	3 1/8	3 3/4	2 5/8	4 1/4	3 7/16	2 5/8	3 1/8	7/8	18 1/4	11	1 9/16	2 7/8	3 3/4	3/4	23 1/2	12 7/8	8 7/16	3 11/16	5 1/4	2 3/4	4 3/4	4 1/2	1
2 3/4	18 5/16	10 7/16	7 3/4	3 1/4	3 15/16	2 3/4	4 1/2	3 9/16	2 3/4	3 1/4	1	21 3/8	11 1/2	1 5/8	3	3 7/8	7/8	24 5/8	13 1/2	8 7/8	3 7/8	5 1/2	2 7/8	4 15/16	4 3/4	1 1/8
2 7/8	19 1/8	11	8 1/16	3 7/16	4 1/8	2 13/16	4 11/16	3 3/4	2 7/8	3 7/16	1	21 3/8	12	1 11/16	3 1/8	4	7/8	25 5/8	14	9 1/4	4	5 3/4	3	5 3/16	5	1 1/8
3	19 15/16	11 7/16	8 7/16	3 9/16	4 5/16	2 15/16	4 7/8	3 15/16	3	3 9/16	1	21 3/8	12 1/2	1 13/16	3 3/8	4 1/4	7/8	26 13/16	14 5/8	9 9/16	4 3/16	6	3 1/8	5 3/8	5 1/4	1 1/8
3 1/8	20 13/16	11 13/16	8 13/16	3 11/16	4 7/16	3 1/8	5 1/16	4 1/16	3 1/8	3 11/16	1 1/8	21 3/8	13	1 7/8	3 1/2	4 3/8	1	27 15/16	15 1/4	10	4 3/8	6 1/4	3 1/4	5 5/8	5 1/2	1 1/4
3 1/4	21 9/16	12 7/16	9 1/8	3 7/8	4 11/16	3 3/16	5 5/16	4 1/8	3 1/4	3 7/8	1 1/8	24 1/2	13 1/2	1 15/16	3 5/8	4 1/2	1	29 1/16	15 7/8	10 7/16	4 9/16	6 1/2	3 3/8	5 7/8	5 3/4	1 1/4
3 3/8	22 3/8	12 13/16	9 1/2	4	4 13/16	3 5/16	5 1/2	4 5/16	3 3/8	4	1 1/8	24 1/2	14	2	3 3/4	4 5/8	1	30 3/16	16 3/8	10 13/16	4 11/16	6 3/4	3 1/2	6 1/16	6 1/8	1 1/4
3 1/2	23 1/4	13 7/16	9 15/16	4 3/16	5 1/16	3 1/2	5 11/16	4 1/2	3 1/2	4 3/16	1 1/4	24 1/2	14 1/2	2 1/16	3 7/8	4 3/4	1 1/8	31 3/16	17 1/8	11 5/16	4 15/16	7	3 5/8	6 1/4	6 3/8	1 1/4
3 5/8	24 1/16	13 13/16	10 5/16	4 5/16	5 3/16	3 5/8	5 7/8	4 11/16	3 5/8	4 5/16	1 1/4	24 1/2	15	2 1/8	4	4 7/8	1 1/8	32 3/8	17 11/16	11 11/16	5 1/8	7 1/4	3 3/4	6 1/2	6 9/16	1 1/4
3 3/4	24 7/8	14 1/4	10 9/16	4 7/16	5 3/8	3 11/16	6 1/8	4 13/16	3 3/4	4 7/16	1 1/4	27 3/4	15 1/2	2 3/16	4 1/8	5	1 1/8	33 1/2	18 1/4	12	5 1/4	7 1/2	3 7/8	6 3/4	6 3/4	1 1/4
3 7/8	25 5/8	14 11/16	10 15/16	4 9/16	5 9/16	3 13/16	6 5/16	5	3 7/8	4 9/16	1 1/4	27 3/4	16	2 1/4	4 1/4	5 1/8	1 1/8	34 11/16	18 7/8	12 7/16	5 7/16	7 3/4	4	7	7	1 1/4
4	26 7/16	15 1/8	11 5/16	4 11/16	5 3/4	3 15/16	6 1/2	5 3/16	4	4 11/16	1 1/4	27 3/4	16 1/2	2 3/8	4 3/8	5 3/8	1 1/8	35 13/16	19 7/16	12 13/16	5 5/8	8	4 1/8	7 1/4	7 1/4	1 1/4
4 1/8	27 3/8	15 11/16	11 5/8	4 7/8	5 15/16	4 1/16	6 11/16	5 5/16	4 1/8	4 7/8	1 1/4	27 3/4	17	2 7/16	4 1/2	5 1/2	1 1/8	36 15/16	20 1/16	13 3/16	5 3/4	8 1/4	4 1/4	7 7/16	7 7/16	1 1/4

NOTE.—The code of dimensioning used in this Table is shown in Fig. 2.

shots of chain or the outboard swivel shots of chain. These test chains shall be heat treated and subjected to the break test loads for chain of that wire size, shown in Table I, in accordance with and subject to the same provisions as specified for the break tests in Section 5.

Proof Tests.

8. *Proof Tests.*—Outboard swivel shots of chain that have met the requirements of the break test described in Section 7 shall be subjected to the proof test loads for chain of that wire size, shown in Table I, in accordance with and subject to the same provisions as specified for the proof tests in Section 6.

Shackles and Shackle Pins:

Break Tests.

9. (*a*) *Break Tests.*—The test chains for the break tests described in Section 5 (*a*), representing shots of chain cable poured from any heat or heats of steel may also represent shackles and shackle pins that are poured from the same heat or heats and shall conform to the requirements of Section 5.

(*b*) In the event that shackles and shackle pins only are poured from any heat or heats of steel, one shackle and shackle pin shall be selected from each such heat of steel. If shackle and shackle pins of more than one size are poured from one heat of steel, the shackle and shackle pin selected for the break test shall be the average wire size. Shackles and shackle pins so selected shall be anchored in an approved static testing machine by connecting with one "E" and one "C" end link of the respective size chain and subjected to the break test load, shown in Table I, for the respective size chain.

(*c*) If the test shackle or shackle pin fails in the break test as described in Paragraph (*b*), then two additional shackles and shackle pins shall be selected and tested individually in accordance with Paragraph (*b*). If either of these shackles or shackle pins fail during this retest, then the shackles and shackle pins represented shall be rejected.

Proof Tests.

10. *Proof Tests.*—All shackles and shackle pins that have met the requirements of the break tests described in Section 9 shall be subjected to the proof test loads for the respective size chain shown in Table I. Shackles and shackle pins shall be proof tested individually, and for anchoring in the static testing machine shall be connected on either end with one "E" and one "C" end link or chain cable of respective size or shackles and shackle pins of the same size in the form of a chain. If the test shackle or shackle pin fails during the test then the shackles and shackle pins represented shall be rejected.

DIMENSIONS AND PERMISSIBLE VARIATIONS

Dimensions.

11. (*a*) All castings of chain links, swivels, shackles and shackle pins shall conform to the dimensions shown in Tables II and III.

Permissible Variations.

(*b*) Permissible variations in dimensions for common "A" links shall conform to the tolerances specified in Table IV. Permissible variations for enlarged links, end links, swivels, shackles and shackle pins shall be permitted in accordance with the tolerances specified in Table IV for common "A" links having the same wire size. In determining the permissible variations for wire diameters, the diameter shall be measured at right angles and one-half the sum of the two measurements shall be considered as representing the wire diameter.

TABLE IV.—PERMISSIBLE VARIATIONS IN DIMENSIONS OF COMMON "A" LINKS, PLUS OR MINUS.

Size of Chain Cable, in.	Wire Diameter, in.	Width, in.	Length, in.
1 and $1\frac{1}{8}$	$\frac{1}{32}$	$\frac{1}{16}$	$\frac{3}{32}$
$1\frac{1}{4}$ " $1\frac{3}{8}$	$\frac{1}{32}$	$\frac{5}{64}$	$\frac{7}{64}$
$1\frac{1}{2}$ " $1\frac{5}{8}$	$\frac{1}{32}$	$\frac{3}{32}$	$\frac{1}{8}$
$1\frac{3}{4}$ " $1\frac{7}{8}$	$\frac{1}{32}$	$\frac{7}{64}$	$\frac{9}{64}$
2 " $2\frac{1}{8}$	$\frac{3}{64}$	$\frac{1}{8}$	$\frac{5}{32}$
$2\frac{1}{4}$ " $2\frac{3}{8}$	$\frac{3}{64}$	$\frac{9}{64}$	$\frac{11}{64}$
$2\frac{1}{2}$ to $2\frac{7}{8}$	$\frac{3}{64}$	$\frac{5}{32}$	$\frac{3}{16}$
3 " $3\frac{3}{8}$	$\frac{1}{16}$	$\frac{11}{64}$	$\frac{13}{64}$
$3\frac{1}{2}$ " $3\frac{7}{8}$	$\frac{1}{16}$	$\frac{3}{16}$	$\frac{7}{32}$
4 " $4\frac{3}{8}$	$\frac{1}{16}$	$\frac{13}{64}$	$\frac{15}{64}$
$4\frac{1}{2}$ " $4\frac{7}{8}$	$\frac{1}{16}$	$\frac{7}{32}$	$\frac{1}{4}$

TABLE V.—MINIMUM WEIGHT PER SHOT OF 15 FATHOMS.

Size of Chain Cable, in.	Weight, lb.	Size of Chain Cable, in.	Weight, lb.
1	855	$2\frac{5}{8}$	5 815
$1\frac{1}{8}$	1085	$2\frac{3}{4}$	6 405
$1\frac{1}{4}$	1345	$2\frac{7}{8}$	7 015
$1\frac{3}{8}$	1625	3	7 650
$1\frac{1}{2}$	1935	$3\frac{1}{8}$	8 320
$1\frac{5}{8}$	2235	$3\frac{1}{4}$	9 010
$1\frac{3}{4}$	2590	$3\frac{3}{8}$	9 725
$1\frac{7}{8}$	2975	$3\frac{1}{2}$	10 475
2	3355	$3\frac{5}{8}$	11 250
$2\frac{1}{8}$	3785	$3\frac{3}{4}$	12 025
$2\frac{1}{4}$	4245	$3\frac{7}{8}$	12 850
$2\frac{3}{8}$	4725	4	13 680
$2\frac{1}{2}$	5265	$4\frac{1}{8}$	14 575

Length. (*c*) The overall length of six links, measuring from every third link, shall be checked. A permissible variation of minus $\frac{1}{8}$ in. or plus $\frac{3}{8}$ in. for each inch of wire diameter shall be permitted on the lengths shown in Table II.

Weight. 12. The weight per shot of 15 fathoms of all chain cable shall not be less than the weight specified in Table V for the respective size chain cable. These minimum weights shall include one connecting link for each 15 fathoms of length.

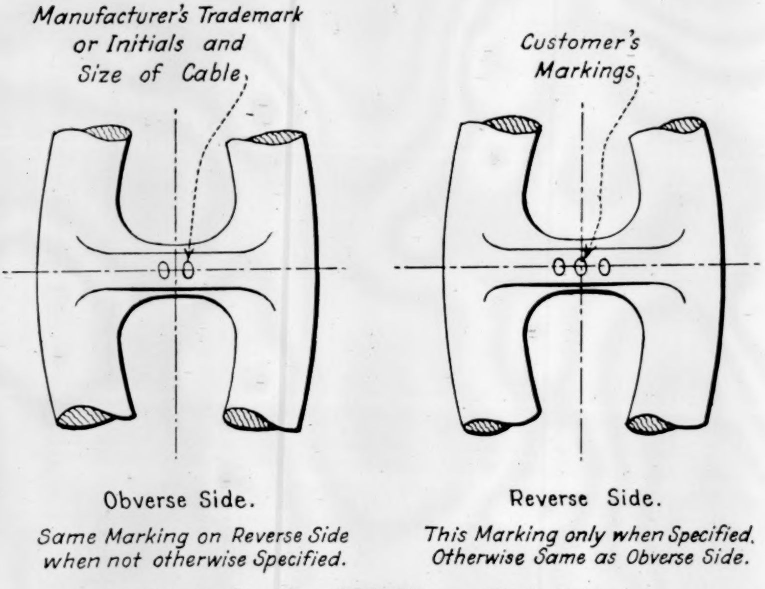

Manufacturer's Trademark or Initials and Size of Cable.
Customer's Markings.
Obverse Side.
Same Marking on Reverse Side when not otherwise Specified.
Reverse Side.
This Marking only when Specified. Otherwise Same as Obverse Side.

FIG. 3.—Location of Markings on Chain Cable.

WORKMANSHIP AND FINISH

Workmanship and Finish. 13. (*a*) The castings shall be free from shrinkage, porosity or other defects in such a location or of such nature as to impair the strength of the chain.

(*b*) All castings shall be cleaned to remove sand and scale. All fins and partings shall be finished in a workmanlike manner.

(*c*) A minor defect of such a nature or in such a location as not to impair the strength or life of the chain may be welded by an approved process if approved by the inspector.

Protective Coating. 14. All parts of the complete chain shall be coated, prior to shipment, with an approved protective coating.

MARKING

15. The manufacturer's trade mark or initials and the size of cable, if used, shall be marked on the cable as shown in Fig. 3. These markings shall be required only on alternate common "A" links unless otherwise agreed upon with the manufacturer. Other markings, including shot numbers, etc., shall be in accordance with the customer's or inspector's requirements. All markings shall appear on the studs of precast links only and shall be raised letters or figures of the maximum height permissible by the size of the stud but not to exceed $\frac{3}{4}$ in. in height by $\frac{1}{8}$ in. in relief. A standard practice of marking shall be followed in so far as possible and shall be the same for all sizes of chain cable. **Marking.**

INSPECTION AND REJECTION

16. Following the proof tests as described in Sections 6, 8, and 10, all shots of chain, swivels, shackles, shackle pins, and other appendages, shall be laid out for surface inspection. Any part showing defects that will be injurious to the strength and service of the chain shall be rejected and replaced subject to the above provisions of the specifications covering the part rejected. **Surface Inspection and Rejection.**

17. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works. **Inspection.**

TENTATIVE SPECIFICATIONS
FOR
STRUCTURAL STEEL FOR LOCOMOTIVES AND CARS[1]

Serial Designation: A 113 – 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1927; REVISED, 1928.

Scope. 1. These specifications apply to shapes, plates (except boiler and firebox plates), rivet steel and bars.

MANUFACTURE

Process. 2. The steel shall be made by the open-hearth process.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition. 3. (*a*) The steel shall conform to the following requirements as to chemical composition:

	Structural Steel for Cars	Structural Steel for Locomotives	Plates for Cold Pressing	Rivet Steel
Phosphorus, per cent { Acid	not over 0.06	not over 0.06	not over 0.06	not over 0.04
Phosphorus, per cent { Basic	" " 0.04	" " 0.04	" " 0.04	" " 0.04
Sulfur, per cent	" " 0.06	" " 0.05	" " 0.06	" " 0.045

(*b*) When copper steel is specified, the following requirement as to copper shall govern:

Copper................................not less than 0.20 per cent

Ladle Analyses. 4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus, and sulfur and also copper when copper steel is specified. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. V. H. Lawrence, Secretary of Committee A-1 on Steel, Alan Wood Iron and Steel Co., Conshohocken, Pa.

These specifications when adopted as standard will supersede the present Standard Specifications for Structural Steel for Locomotives (Serial Designation: A 10 – 24) and Specifications for Structural Steel for Cars (Serial Designation: A 11 – 24), 1927 Book of A.S.T.M. Standards, Part I, pp. 87–98.

Check Analyses.

5. Analyses may be made by the purchaser from finished material representing each melt. The phosphorus and sulfur content thus determined shall not exceed that specified in Section 3 by more than 25 per cent.

PHYSICAL PROPERTIES AND TESTS

Tension Tests.

6. (*a*) The material, except as specified in Paragraph (*c*), shall conform to the following requirements as to tensile properties:

Properties Considered	Structural Steel for Cars	Structural Steel for Locomotives	Plates for Cold Pressing	Rivet Steel
Tensile strength, lb. per sq. in.	50 000 - 65 000	55 000 - 65 000	48 000 - 58 000	45 000 - 60 000
Yield point, min., lb. per sq. in.	0.5 tens. str.	0.5 tens. str.	0.5 tens. str.	0.5 tens. str.
Elongation in 8 in.,[a] min., per cent	$\frac{1\,500\,000}{\text{Tens. str.}}$	$\frac{1\,500\,000}{\text{Tens. str.}}$	$\frac{1\,500\,000}{\text{Tens. str.}}$	$\frac{1\,500\,000}{\text{Tens. str.}}$
Elongation in 2 in., min. per cent	22	22	..	..

[a] See Section 7.

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

(*c*) Plates $\frac{3}{16}$ in. and under in thickness, shapes less than 1 sq. in. in cross-section, flats $\frac{3}{16}$ in. and under in thickness, and other bars, except rivet rods, less than $\frac{1}{2}$ in. in thickness or diameter, need not be subjected to tension tests.

Modifications in Elongation.

7. (*a*) For material over $\frac{3}{4}$ in. in thickness, a deduction from the percentage of elongation in 8 in. specified in Section 6 (*a*) of 0.25 per cent shall be made for each increase of $\frac{1}{32}$ in. of the specified thickness above $\frac{3}{4}$ in., to a minimum of 18 per cent.

(*b*) For material under $\frac{5}{16}$ in. in thickness, a deduction from the percentage of elongation in 8 in. specified in Section 6 (*a*) of 1.25 per cent shall be made for each decrease of $\frac{1}{32}$ in. of the specified thickness below $\frac{5}{16}$ in.

Bend Tests.

8. (*a*) Bend test specimens for structural steel shall stand being bent cold through 180 deg. without cracking on the outside of the bent portion as follows: For material $\frac{3}{4}$ in. or under in thickness, flat on itself; for material over $\frac{3}{4}$ in. to and including $1\frac{1}{4}$ in. in thickness, around a pin the diameter of which is equal to the thickness of the specimen; and for material over $1\frac{1}{4}$ in. in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen.

(*b*) Bend test specimens for rivet steel and plates for cold pressing shall stand being bent cold through 180 deg. flat on themselves without cracking on the outside of the bent portion.

Test Specimens.

9. (*a*) Test specimens shall be prepared for testing from the material in its rolled condition, except as specified in Paragraph (*b*).

(*b*) Test specimens for rivet bars which have been cold-drawn shall be normalized before testing.

(*c*) Test specimens shall be taken longitudinally and, except as specified in Paragraphs (*e*) and (*f*), shall be of the full thickness or section of material as rolled.

(*d*) Test specimens for plates, shapes, and flats may be machined to the form and dimensions shown in Fig. 1, or with both edges parallel.

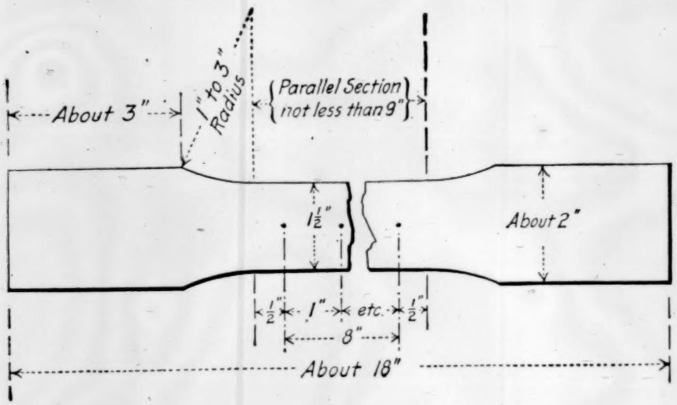
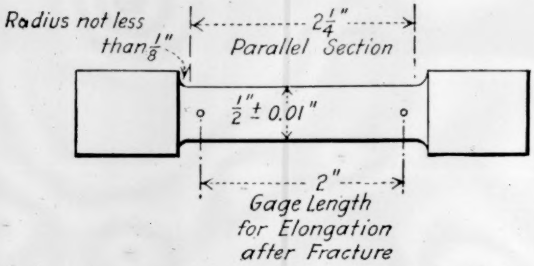

About 3"
1" to 3" Radius
Parallel Section not less than 9"
1½"
About 2"
½"
1"
etc.
½"
8"
About 18"

FIG. 1.


Radius not less than ⅛"
2¼"
Parallel Section
½" ± 0.01"
2"
Gage Length for Elongation after Fracture

Note:- The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 2.

(*e*) Tension test specimens for material over 1½ in. in thickness or diameter may be machined to a thickness or diameter of at least ¾ in. for a length of at least 9 in., or they may conform to the dimensions shown in Fig. 2.

(*f*) Bend test specimens for material over 1½ in. in thickness or diameter may be machined to a thickness or diameter of at least ¾ in. or to 1 by ½ in. in section.

(*g*) The machined sides of rectangular bend test specimens may have the corners rounded to a radius of not over $\frac{1}{16}$ in.

Number of Tests.

10. (*a*) One tension and one bend test shall be made from each melt; except that if material from one melt differs ⅜ in. or more in

thickness, one tension and one bend test shall be made from both the thickest and the thinnest material rolled.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 6 (*a*) and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length of a 2-in. specimen or is outside the middle third of the gage length of an 8-in. specimen, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

TABLE I.—PERMISSIBLE VARIATIONS OF RECTANGULAR PLATES ORDERED TO WEIGHT.

ORDERED WEIGHT, LB. PER SQ. FT.	Permissible Variations in Average Weights per Square Foot of Plates for Widths Given, Expressed in Percentages of Ordered Weights. Under 48 in.		48 to 60 in., excl.		60 to 72 in., excl.		72 to 84 in., excl.		84 to 96 in., excl.		96 to 108in., excl.		108 to 120in., excl.		120 to 132in., excl.		132 in. or over		ORDERED WEIGHT, LB. PER SQ. FT.
	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	
Under 5............	5	3	5.5	3	6	3	7	3	...	...	...	...	...	...	...	...	...	...	Under 5
5 to 7.5 exclusive.	4.5	3	5	3	5.5	3	6	3	...	...	...	...	...	...	...	...	...	...	5 to 7.5 exclusive
7.5 to 10 exclusive.	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	...	...	...	...	7.5 to 10 exclusive
10 to 12.5 exclusive.	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	9	3	10 to 12.5 exclusive
12.5 to 15 exclusive.	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	12.5 to 15 exclusive
15 to 17.5 exclusive.	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	15 to 17.5 exclusive
17.5 to 20 exclusive.	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	17.5 to 20 exclusive
20 to 25 exclusive.	2	2	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	20 to 25 exclusive
25 to 30 exclusive.	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	5	3	25 to 30 exclusive
30 to 40 exclusive.	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	30 to 40 exclusive
40 or over..........	2	2	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	40 or over

NOTE.—The weight per square foot of individual plates shall not vary from the ordered weight by more than $1\frac{1}{3}$ times the amount given in this table.

PERMISSIBLE VARIATIONS IN WEIGHT AND DIMENSIONS

Permissible Variations.

11. (*a*) One cubic inch of rolled steel is assumed to weigh 0.2833 lb. The cross-sectional area or weight of each structural-size shape and of each universal mill plate up to and including 36 in. in width shall not vary more than 2.5 per cent from the theoretical or specified amounts. The thickness or weight of rectangular sheared mill plates and of rectangular universal mill plates over 36 in. in width shall conform to the requirements of Paragraphs (*b*) and (*c*); the cross-sectional area or weight of bar size[1] angles, tees, zees, and channels shall conform to the requirements of Paragraph (*d*); and the cross-sectional dimensions of bars shall conform to the requirements of Paragraph (*e*).

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[1] A channel is in "bar" size when its greatest dimension is less than 3 in. An angle, tee or zee is in "bar" size when its greatest dimension is less than 3 in., or when it is 3 in. or more and at the same time the thickness is less than $\frac{1}{4}$ in.

(*b*) *When Ordered to Weight per Square Foot:* The weight of each lot[1] of plates in each shipment shall not vary from the weight ordered more than the amounts given in Table **I**.

(*c*) *When Ordered to Thickness:* The thickness of each plate shall not vary more than 0.01 in. under that ordered.

TABLE II.—PERMISSIBLE OVERWEIGHTS OF RECTANGULAR PLATES ORDERED TO THICKNESS.

ORDERED THICKNESS, IN.	Permissible Excess in Average Weights per Square Foot of Plates for Widths Given, Expressed in Percentages of Nominal Weights.									ORDERED THICKNESS, IN.
	Under 48 in.	48 to 60 in., excl.	60 to 72 in., excl.	72 to 84 in., excl.	84 to 96 in., excl.	96 to 108 in., excl.	108 to 120 in., excl.	120 to 132 in., excl.	132 in. or over	
Under $\frac{1}{8}$..........	9	10	12	14	....	....	....	....	....	Under $\frac{1}{8}$
$\frac{1}{8}$ to $\frac{3}{16}$ exclusive	8	9	10	12	....	....	....	....	....	$\frac{1}{8}$ to $\frac{3}{16}$ exclusive
$\frac{3}{16}$ to $\frac{1}{4}$ exclusive	7	8	9	10	12	....	....	....	....	$\frac{3}{16}$ to $\frac{1}{4}$ exclusive
$\frac{1}{4}$ to $\frac{5}{16}$ exclusive	6	7	8	9	10	12	14	16	19	$\frac{1}{4}$ to $\frac{5}{16}$ exclusive
$\frac{5}{16}$ to $\frac{3}{8}$ exclusive	5	6	7	8	9	10	12	14	17	$\frac{5}{16}$ to $\frac{3}{8}$ exclusive
$\frac{3}{8}$ to $\frac{7}{16}$ exclusive	4.5	5	6	7	8	9	10	12	15	$\frac{3}{8}$ to $\frac{7}{16}$ exclusive
$\frac{7}{16}$ to $\frac{1}{2}$ exclusive	4	4.5	5	6	7	8	9	10	13	$\frac{7}{16}$ to $\frac{1}{2}$ exclusive
$\frac{1}{2}$ to $\frac{5}{8}$ exclusive	3.5	4	4.5	5	6	7	8	9	11	$\frac{1}{2}$ to $\frac{5}{8}$ exclusive
$\frac{5}{8}$ to $\frac{3}{4}$ exclusive	3	3.5	4	4.5	5	6	7	8	9	$\frac{5}{8}$ to $\frac{3}{4}$ exclusive
$\frac{3}{4}$ to 1 exclusive	2.5	3	3.5	4	4.5	5	6	7	8	$\frac{3}{4}$ to 1 exclusive
1 or over..........	2.5	2.5	3	3.5	4	4.5	5	6	7	1 or over

NOTE.—The weight of individual plates ordered to thickness shall not exceed the nominal weight by more than one and one-third the amount given in this table.

TABLE III.—PERMISSIBLE VARIATIONS IN WEIGHT OF BAR SIZES OF ANGLES, TEES, ZEES, AND CHANNELS.

Dimensions, in.	Thickness, in.	Variations, expressed in percentages of Nominal Weights
Any dimension over $1\frac{1}{2}$..	Over $\frac{3}{16}$	4 over and under
All dimensions $1\frac{1}{2}$ and less..	Over $\frac{3}{16}$	5 " " "
Any dimension over $1\frac{1}{2}$..	$\frac{3}{16}$ and less	6 " " "
All dimensions $1\frac{1}{2}$ and less..	$\frac{3}{16}$ and less	7 " " "

The overweight in each lot[1] of plates in each shipment shall not exceed the amount given in Table II.

(*d*) The weight of each lot[2] of bar sizes of angles, tees, zees, and channels in each shipment shall not vary from the weight ordered more than the amounts given in Table III.

(*e*) The cross-sectional dimension of bars shall not vary from the size ordered more than the amounts given in Tables IV and V.

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[1] The term "lot" as applied to Table I means all the plates of each group width and group weight. As applied to Table II, it means all the plates of each group width and group thickness.

[2] The term "lot" here means all of the bars of each group dimension and group thickness shown in Table III.

12. Except in cases of special agreement between the purchaser and manufacturer that the material shall be furnished recut to exact ordered dimensions, the length of all shapes, plates, and bars shall not vary under the dimensions ordered more than $\frac{1}{4}$ in. The width of plates shall not vary under the dimensions ordered more than $\frac{1}{4}$ in. for sheared mill plates **nor** more than $\frac{1}{8}$ in. for universal mill plates. The variation over the dimension ordered shall not be more than is consistent with thickness, length, and good mill practice.

TABLE IV.—PERMISSIBLE VARIATIONS IN CROSS-SECTIONAL DIMENSIONS OF ROUNDS, SQUARES AND HEXAGONS.

Dimensions, in.	Variations, in.	
	Over	Under
Up to and including $\frac{1}{2}$	0.007	0.007
Over $\frac{1}{2}$ up to and including 1	0.010	0.010
Over 1 " " " " 2	$\frac{1}{32}$	$\frac{1}{64}$
Over 2 " " " " 3	$\frac{3}{64}$	$\frac{1}{32}$
Over 3 " " " " 5	$\frac{3}{32}$	$\frac{1}{32}$
Over 5 " " " " 8	$\frac{1}{8}$	$\frac{1}{16}$

TABLE V.—PERMISSIBLE VARIATIONS IN CROSS-SECTIONAL DIMENSION OF FLATS.

Dimensions, in.	Variations in Width, in.		Variations in Thickness, Over and Under, from Thickness Specified, in.			
	Over	Under	$\frac{3}{16}$ in. and Under	Over $\frac{3}{16}$ in. up to $\frac{1}{2}$ in., inclusive	Over $\frac{1}{2}$ in. up to 1 in., inclusive	Over 1 in. up to 2 in., inclusive
Up to and including 1	$\frac{1}{32}$	$\frac{1}{64}$	0.006	0.008	0.010	..
Over 1 up to and including 2	$\frac{3}{64}$	$\frac{1}{32}$	0.008	0.012	0.015	$\frac{1}{32}$
Over 2 " " " " 4	$\frac{1}{16}$	$\frac{3}{64}$	0.010	0.015	0.020	$\frac{1}{32}$
Over 4 " " " " 6	$\frac{3}{32}$	$\frac{1}{16}$	0.010	0.015	0.020	$\frac{1}{32}$

FINISH

13. The finished material shall be free from injurious defects and have a workmanlike finish. **Finish.**

MARKING

14. The name or brand of the manufacturer and the melt number shall be legibly rolled or stamped on all finished material, except that rivet bars and other small sections shall, when loaded for shipment, be properly separated and marked for identification. The melt number shall be legibly marked, by stamping if practicable, on each test specimen. **Marking.**

INSPECTION AND REJECTION

Inspection. 15. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications.

All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 16. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples.

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing. 17. Samples tested in accordance with Section 5, which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

TENTATIVE SPECIFICATIONS
FOR
MARINE BOILER STEEL PLATES[1]

Serial Designation: A 114 - 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1927; REVISED, 1928.

Scope. 1. These specifications cover two grades of steel for marine boilers, namely: Grade A and Grade B.

MANUFACTURE

Process. 2. The steel shall be made by the open-hearth process.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition. 3. The steel shall conform to the following requirements as to chemical composition:

Phosphorus	Acid	not over 0.04 per cent
	Basic	" " 0.035 " "
Sulfur		" " 0.04 " "

Ladle Analyses. 4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus, and sulfur. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative and the percentages of phosphorus and sulfur shall conform to the requirements specified in Section 3.

Check Analyses. 5. An analysis may be made by the purchaser from the tension test specimen representing the bottom of each plate as rolled. The chemical composition thus determined shall conform to the requirements specified in Section 3.

PHYSICAL PROPERTIES AND TESTS

Tension Tests. 6. (*a*) The material shall conform to the following requirements as to tensile properties:

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. V. H. Lawrence, Secretary of Committee A-1 on Steel, Alan Wood Iron and Steel Co., Conshohocken, Pa.

	GRADE A	GRADE B
Tensile strength, lb. per sq. in....	60 000 – 70 000	55 000 – 65 000
Yield point, min., lb. per sq. in....	0.5 tens. str.	0.5 tens. str.
Elongation in 8 in., min., per cent.	$\frac{1\ 500\ 000}{\text{tens. str.}}$	$\frac{1\ 550\ 000}{\text{tens. str.}}$

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

Modification in Elongation. 7. For material over ¾ in. in thickness, a deduction from the percentages of elongation specified in Section 6 (*a*) of 0.125 per cent shall be made for each increase of $\frac{1}{32}$ in. of the specified thickness above ¾ in. to a minimum of 20 per cent for Grade A steel and 22 per cent for Grade B steel.

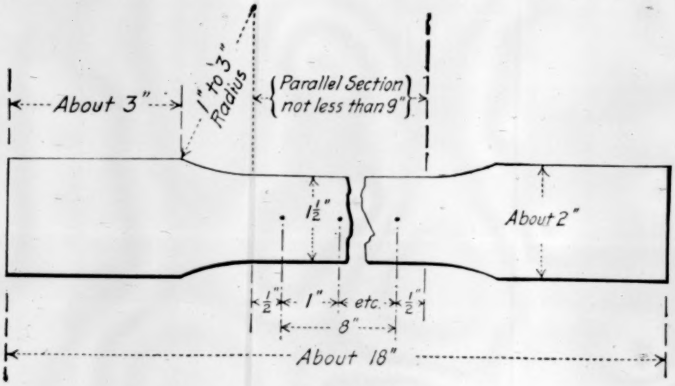

FIG. 1.

Bend Tests. 8. (*a*) The test specimen for Grade A steel shall stand being bent cold through 180 deg. without cracking on the outside of the bent portion, as follows: For material 1 in. or under in thickness, around a pin the diameter of which is equal to 1½ times the thickness of the specimen; for material over 1 in. to and including 1½ in. in thickness, around a pin the diameter of which is equal to three times the thickness of the specimen; and for material over 1½ in. in thickness, around a pin the diameter of which is equal to four times the thickness of the specimen.

(*b*) The test specimen for Grade B steel shall stand being bent cold through 180 deg. without cracking on the outside of the bent portion, as follows: For material 1 in. or under in thickness, around a pin the diameter of which is equal to the thickness of the specimen; for material over 1 in. to and including 1½ in. in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen; and for material over 1½ in. in thickness, around a pin the diameter of which is equal to three times the thickness of the specimen.

Test Specimens.

9. (*a*) The tension test specimens shall be taken longitudinally from the finished rolled material. In the case of plates rolled from ingots, these specimens shall be taken in the direction of the longitudinal axis of the ingot; one from the top and one from the bottom on the same side of the plates as rolled. In the case of plates rolled from slabs, the tension test specimens shall be taken from diagonal corners.

In the case of plates rolled from ingots, the bend test specimen shall be taken from the middle of the top of the finished rolled material at right angles to the longitudinal axis of the ingot. In the case of plates rolled from slabs, it shall be taken from the middle of one end at right angles to the longitudinal axis of the plate as rolled.

TABLE I.—PERMISSIBLE OVERWEIGHTS OF RECTANGULAR PLATES ORDERED TO THICKNESS.

ORDERED THICKNESS, IN.	PERMISSIBLE EXCESS IN AVERAGE WEIGHTS PER SQUARE FOOT OF PLATES FOR WIDTHS GIVEN, EXPRESSED IN PERCENTAGES OF NOMINAL WEIGHTS.									ORDERED THICKNESS, IN.
	Under 48 in.	48 to 60 in., excl.	60 to 72 in., excl.	72 to 84 in., excl.	84 to 96 in., excl.	96 to 108 in., excl.	108 to 120 in., excl.	120 to 132 in., excl.	132 in. or over.	
Under $\frac{1}{8}$	9	10	12	14	..	..	..	..	..	Under $\frac{1}{8}$
$\frac{1}{8}$ to $\frac{3}{16}$ excl.	8	9	10	12	..	..	..	..	..	$\frac{1}{8}$ to $\frac{3}{16}$ excl.
$\frac{3}{16}$ to $\frac{1}{4}$ excl.	7	8	9	10	12	..	..	..	..	$\frac{3}{16}$ to $\frac{1}{4}$ excl.
$\frac{1}{4}$ to $\frac{5}{16}$ excl.	6	7	8	9	10	12	14	16	19	$\frac{1}{4}$ to $\frac{5}{16}$ excl.
$\frac{5}{16}$ to $\frac{3}{8}$ excl.	5	6	7	8	9	10	12	14	17	$\frac{5}{16}$ to $\frac{3}{8}$ excl.
$\frac{3}{8}$ to $\frac{7}{16}$ excl.	4.5	5	6	7	8	9	10	12	15	$\frac{3}{8}$ to $\frac{7}{16}$ excl.
$\frac{7}{16}$ to $\frac{1}{2}$ excl.	4	4.5	5	6	7	8	9	10	13	$\frac{7}{16}$ to $\frac{1}{2}$ excl.
$\frac{1}{2}$ to $\frac{5}{8}$ excl.	3.5	4	4.5	5	6	7	8	9	11	$\frac{1}{2}$ to $\frac{5}{8}$ excl.
$\frac{5}{8}$ to $\frac{3}{4}$ excl.	3	3.5	4	4.5	5	6	7	8	9	$\frac{5}{8}$ to $\frac{3}{4}$ excl.
$\frac{3}{4}$ to 1 excl.	2.5	3	3.5	4	4.5	5	6	7	8	$\frac{3}{4}$ to 1 excl.
1 or over	2.5	2.5	3	3.5	4	4.5	5	6	7	1 or over

(*b*) Tension and bend test specimens shall be of the full thickness of the material as rolled, and shall be machined to the form and dimensions shown in Fig. 1; except that bend test specimens may be machined with both edges parallel.

(*c*) The machined sides of rectangular bend test specimens may have the corners rounded to a radius not over $\frac{1}{16}$ in.

Number of Tests.

10. (*a*) Two tension tests and one bend test shall be made from each plate as rolled.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 6 (*a*) and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

PERMISSIBLE VARIATIONS IN WEIGHT AND THICKNESS

Permissible Variations.

11. The thickness of each plate shall not vary more than 0.01 in. under that ordered. The overweight of each "lot[1] in each shipment" shall not exceed the amount given in Table I. One cubic inch of rolled steel is assumed to weigh 0.2833 lb.

FINISH

Finish.

12. The finished material shall be free from injurious defects and shall have a workmanlike finish.

MARKING

Marking.

13. (*a*) The name or brand of the manufacturer, the manufacturer's test identification number, Marine "A" or "B," and lowest tensile strength specified shall be legibly stamped on each finished plate in two places about 18 in. from the edges and on each butt strap near the center line about 18 in. from one end. The manufacturer's test identification number shall be legibly stamped on each test specimen.

(*b*) When required, the monogram stamp of the classification societies and the Department of Commerce shall be placed on each plate adjacent to the stamping specified in Paragraph (*a*).

INSPECTION AND REJECTION

Inspection.

14. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

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[1] The term lot means all of the plates of each group width and group thickness.

15. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples. **Rejection.**

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

16. Samples tested in accordance with Section 5, which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time. **Rehearing**

TENTATIVE SPECIFICATIONS
FOR
CARBON-STEEL CASTINGS FOR VALVES, FLANGES AND FITTINGS FOR HIGH-TEMPERATURE SERVICE[1]

Serial Designation: A 95 - 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1925; REVISED, 1926, 1928.

Scope. 1. These specifications cover carbon-steel castings for valves, flanges and fittings for high-temperature service (Note 1).

MANUFACTURE

Process. 2. The steel shall be made by one or more of the following processes: open-hearth, electric-furnace, converter or crucible.

Heat Treatment. 3. (*a*) All castings shall receive a heat treatment proper to the design and chemical composition of the castings.

(*b*) Heat treatment, unless otherwise specified by the purchaser, may consist of annealing, or of normalizing, or of normalizing followed by annealing, or of normalizing followed by a draw-back to a temperature below the critical range. No castings which have been quenched in any liquid medium shall be offered under these specifications.

(*c*) *Annealing.*—The procedure for annealing shall consist in allowing the castings to cool, after pouring, to a temperature below the critical range. They shall then be uniformly reheated to the proper temperature to refine the grain and allowed to cool uniformly in the furnace.

(*d*) *Normalizing.*—The procedure for normalizing shall consist in allowing the castings to cool, after pouring, to a temperature below the critical range. They shall then be reheated to the proper temperature to refine the grain and allowed to cool in still air.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition. 4. (*a*) The castings shall conform to the following requirements as to chemical composition, except that the following limitations for carbon, manganese and silicon are intended to show desired composition and are not to be used for rejection:

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. V. H. Lawrence, Secretary of Committee A-1 on Steel, Alan Wood Iron and Steel Co., Conshohocken, Pa.

Carbon	0.15 – 0.40	per cent
Manganese	not under 0.50	"
Silicon	not under 0.20	"
Phosphorus	not over 0.05	"
Sulfur	not over 0.05	"

(*b*) Manufacturers submitting proposals to furnish material under these specifications shall specify, with their proposals, the limits of carbon, manganese and silicon which they will accept as a basis for rejection.

Ladle Analyses.

5. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 4. This analysis shall be made from drillings taken at least ¼ in. beneath the surface of a test ingot obtained during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative and shall conform to the requirements specified in Section 4.

Check Analyses.

6. Analyses may be made by the purchaser from the broken tension test specimen or from a casting representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 4. Samples for analysis shall be taken not less than ¼ in. beneath the surface, except in the case of castings which are too thin, and shall be taken in such a manner as not to impair the usefulness of the casting.

PHYSICAL PROPERTIES AND TESTS

Tension Tests.

7. (*a*) The castings shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in.	70 000
Yield point, lb. per sq. in.	36 000
Elongation in 2 in., per cent	22
Reduction of area, per cent	30

(*b*) The yield point shall be determined by the drop of the beam of the testing machine at a cross-head speed not to exceed ⅛ in. per minute. The tensile strength shall be determined at a speed not to exceed 1½ in. per minute.

Bend Test.

8. (*a*) Bend tests shall be required for castings only when so specified in the order.

(*b*) When a bend test is specified, the test specimens shall stand being bent cold through an angle of 90 deg. around a pin 1 in. in diameter, without cracking on the outside of the bent portion.

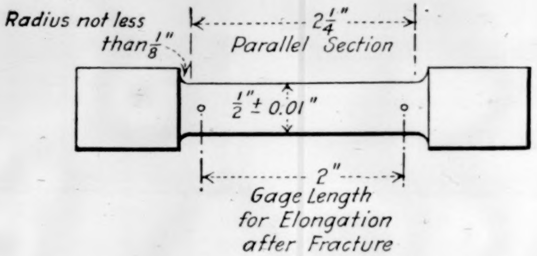
Hydrostatic Tests.

9. Each casting shall be tested after machining to the hydrostatic pressures specified in the table below (Note 1), and shall show no leaks. Castings ordered under these specifications for working pressures other than those listed below, shall be tested to such pressures as may be agreed upon:

CLASS OF CASTINGS, WORKING STEAM PRESSURE, LB. PER SQ. IN.	STANDARD TEST PRESSURE, LB. PER SQ. IN.
250	750
400	1000
600	1500
900	2000
1350	3000

Test Specimens.

10. (*a*) Tension test specimens, and, when a bend test is specified, bend test specimens, shall be taken from test bars cast attached to the castings where practicable. If the design of the castings is such that test bars should not be attached to the castings, the test bars shall be cast attached to special blocks, a sufficient number of which shall be provided for each lot of castings. Test bars from which tension and bend test specimens are to be taken shall remain attached to the castings or blocks they represent through heat treatment and until presented for inspection. Test bars shall be provided in sufficient numbers to furnish the tests required in Section 11.


Radius not less than $\frac{1}{8}$"
$2\frac{1}{4}$"
Parallel Section
$\frac{1}{2}$" ± 0.01"
2"
Gage Length for Elongation after Fracture

Note:- The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 1.

(*b*) If satisfactory to the manufacturer and inspector, tension test specimens may be cut from heat-treated castings, instead of from test bars.

(*c*) Tension test specimens shall conform to the dimensions shown in Fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

(*d*) Bend test specimens shall be machined to 1 by $\frac{1}{2}$ in. in section with the corners rounded to a radius of not over $\frac{1}{16}$ in.

Number of Tests.

11. (*a*) One tension test and, when specified, one bend test shall be made from each melt in each heat-treatment charge and, when specified, from each casting weighing 500 lb. or over.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded; in which case another specimen from the same lot shall be substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 7 (*a*) and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

Retests.

12. If the results of the physical tests for any lot do not conform to the requirements specified, such lot may be re-treated, but not more than twice. Retests shall be made as specified in Sections 7 and 8.

WORKMANSHIP AND FINISH

Workmanship.

13. The castings shall conform substantially to the shapes and sizes indicated by the patterns and drawings submitted by the purchaser.

Finish.

14. (*a*) The castings shall be clean and free from injurious defects.

(*b*) The castings shall not be peened to stop leaks.

Welding.

(*c*) Defects which do not impair the strength of the castings may be welded by an approved process. The defects shall be cleaned out to solid metal, before welding, and when so required by the inspector, shall be submitted to him in this condition for his approval. All castings shall be heat-treated after welding in accordance with the requirements in Section 3, except that with permission of the inspector, castings with minor welds need not be re-heat-treated.

INSPECTION AND REJECTION

Inspection.

15. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the castings ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the castings are being furnished in accordance with these specifications.

(*b*) If, in the case of important castings for special purposes, surface inspection in the green state is required, this shall be so specified in the order.

(*c*) All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 16. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 6 shall be reported within twelve working days from the receipt of samples.

(*b*) Castings which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected and the manufacturer shall be notified.

Rehearing. 17. Samples tested in accordance with Section 6, which represent rejected castings, shall be preserved for two weeks from the date of transmission of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

EXPLANATORY NOTE

NOTE 1.—This contemplates temperatures up to 750° F. (400° C.); or at the discretion of the designing engineer higher temperatures with appropriate pressures may be used. Reference may be made to the dimensional standards for pressures and temperatures formulated by the Sectional Committee on Standardization of Pipe Flanges and Fittings, under the sponsorship of the Heating and Piping Contractors National Association, Manufacturers Standardization Society of the Valve and Fittings Industry and the American Society of Mechanical Engineers, and organized under the procedure of the American Engineering Standards Committee. The hydrostatic test pressures shown in Section 9 were taken from the above standards.

TENTATIVE SPECIFICATIONS
FOR
BLACK AND HOT-DIPPED ZINC-COATED (GALVANIZED) WELDED AND SEAMLESS STEEL PIPE FOR ORDINARY USES[1]

Serial Designation: A 120 - 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1928.

1. These specifications cover black and hot-dipped galvanized "standard weight," "extra strong," and "double extra strong" welded and seamless steel pipe. Pipe ordered under these specifications is intended for ordinary uses such as low pressure service in steam, water and gas lines, and is not intended for close bending or coiling, or high-temperature service. **Scope.**

MANUFACTURE

2. (*a*) The steel for welded pipe shall be soft weldable quality made by the bessemer or by the open-hearth process. The steel for seamless pipe shall be made by the open-hearth or electric-furnace process. **Process.**

(*b*) Welded pipe 3 in. or under in nominal diameter may be butt-welded, unless otherwise specified. Welded pipe over 3 in. in nominal diameter shall be lap-welded.

3. Galvanized pipe shall be coated with zinc inside and outside by the hot-dip process. **Galvanized Pipe.**

HYDROSTATIC TESTS

4. Each length of pipe shall be tested at the mill to the hydrostatic pressures specified in Table I. Welded pipe 2 in. and larger shall be jarred near one end while under test pressure. **Hydrostatic Tests.**

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. V. H. Lawrence, Secretary of Committee A-1 on Steel, Alan Wood Iron and Steel Co., Conshohocken, Pa.

STANDARD WEIGHTS

Standard Weights. 5. (*a*) The standard weights for pipe of various inside diameters are given in Table II.

(*b*) Nipples shall be cut from pipe of the same weight and quality as described in these specifications.

Permissible Variations. 6. The weight of the pipe shall not vary more than 5 per cent for standard weight and extra strong pipe nor more than 10 per cent for double extra strong pipe from that specified in Table II.

Lengths. 7. Unless otherwise specified, pipe shall be furnished as to lengths in accordance with the following regular practice:

TABLE I.—HYDROSTATIC PRESSURES FOR WELDED AND SEAMLESS STEEL PIPE.
(Pressures Expressed in Pounds per Square Inch)

Size (Nominal Inside Diameter), in.	"Standard" Pipe			"Extra Strong" Pipe			"Double Extra Strong" Pipe	
	Weight of Pipe per Linear Foot, Threaded and with Couplings	Butt-weld	Lap-weld and Seamless	Weight of Pipe per Linear Foot, Plain Ends, lb.	Butt-weld	Lap-weld and Seamless	Butt-weld	Lap-weld and Seamless
$\frac{1}{8}$	.....	700	....	.....	700	....	....	....
$\frac{1}{4}$	.....	700	....	.....	700	....	....	....
$\frac{3}{8}$	.....	700	....	.....	700	....	....	....
$\frac{1}{2}$	.....	700	....	.....	700	....	700	....
$\frac{3}{4}$	.....	700	....	.....	700	....	700	....
1	.....	700	....	.....	700	....	700	....
$1\frac{1}{4}$	.....	700	1000	.....	1500	2500	2200	....
$1\frac{1}{2}$	.....	700	1000	.....	1500	2500	2200	3000
2	.....	700	1000	.....	1500	2500	2200	3000
$2\frac{1}{2}$	.....	800	1000	.....	1500	2000	2200	3000
3	.....	800	1000	.....	1500	2000	2200	3000
$3\frac{1}{2}$	.....	...	1000	.....	....	2000	....	2500
4	.....	...	1000	.....	....	2000	....	2500
5	.....	...	1000	.....	....	1800	....	2000
6	.....	...	1000	.....	....	1800	....	2000
8	25.00	...	800	.....	....	....	....	2000
8	28.81	...	1000	43.39	....	1500	....	...
10	32.00	...	600	.....	....	....	....	....
10	35.00	...	700	.....	....	....	....	....
10	41.13	...	900	54.74	....	1000	....	....
12	45.00	...	600	.....	....	....	....	....
12	50.71	...	800	65.42	....	1000	....	....

For pipes over 12 in. in inside diameter, the test pressures should be calculated by the formula $P = \frac{2 S_t}{D}$ in which P = pressure in pounds per square inch; S = fiber stress, 12,000 lb. per sq. in.; t = thickness of wall in inches: D = outside diameter in inches.

(*a*) Standard weight pipe shall be in random lengths of 16 to 22 ft., but not more than 5 per cent of the total number of lengths may be "jointers," which are two pieces coupled together. When ordered with plain ends, 5 per cent may be in lengths of 12 to 16 ft.

(*b*) Extra strong and double extra strong pipe shall be in random lengths of 12 to 22 ft. Five per cent may be in lengths of 6 to 12 ft.

WORKMANSHIP AND FINISH

Workmanship. 8. For pipe 1½ in. or under in nominal size, the outside diameter at any point shall not vary more than $\frac{1}{64}$ in. over nor more than $\frac{1}{32}$ in. under the standard outside diameter. For pipe 2 in. or over in nominal size, the outside diameter shall not vary more than 1 per cent over or under the standard outside diameter. The wall thickness shall not be more than 12.5 per cent under the nominal wall thickness at any point.

TABLE II.—STANDARD WEIGHTS AND DIMENSIONS OF WELDED AND SEAMLESS STEEL PIPE.

Size (Nominal Inside Diameter), in.	Outside Diameter, in.	"Standard" Pipe			"Extra Strong" Pipe		"Double Extra Strong" Pipe	
		Number of Threads per Inch	Thickness, in.	Weight of Pipe per Linear Foot, Threaded and with Couplings, lb.	Thickness, in.	Weight of Pipe per Linear Foot, Plain Ends, lb.	Thickness, in.	Weight of Pipe per Linear Foot, Plain Ends, lb.
⅛	0.405	27	0.068	0.25	0.095	0.31	.....	.....
¼	0.540	18	0.088	0.43	0.119	0.54	.....	.....
⅜	0.675	18	0.091	0.57	0.126	0.74	.....	.....
½	0.840	14	0.109	0.85	0.147	1.09	0.294	1.71
¾	1.050	14	0.113	1.13	0.154	1.47	0.308	2.44
1	1.315	11½	0.133	1.68	0.179	2.17	0.358	3.66
1¼	1.660	11½	0.140	2.28	0.191	3.00	0.382	5.21
1½	1.900	11½	0.145	2.73	0.200	3.63	0.400	6.41
2	2.375	11½	0.154	3.68	0.218	5.02	0.436	9.03
2½	2.875	8	0.203	5.82	0.276	7.66	0.552	13.70
3	3.500	8	0.216	7.62	0.300	10.25	0.600	18.58
3½	4.000	8	0.226	9.20	0.318	12.51	0.636	22.85
4	4.500	8	0.237	10.89	0.337	14.98	0.674	27.54
5	5.563	8	0.258	14.81	0.375	20.78	0.750	38.55
6	6.625	8	0.280	19.19	0.432	28.57	0.864	53.16
*8	8.625	8	0.277	25.00	.....	.....	0.875	72.42
8	8.625	8	0.322	28.81	0.500	43.39	.....	.....
*10	10.750	8	0.279	32.00	.....	.....	.....	.....
*10	10.750	8	0.307	35.00	.....	.....	.....	.....
10	10.750	8	0.365	41.13	0.500	54.74	.....	.....
*12	12.750	8	0.330	45.00	.....	.....	.....	.....
12	12.750	8	0.375	50.71	0.500	65.42	.....	.....

* Unless specifically stated on the order the lighter weights will not be furnished. Weights given in the table are for pipes up to and including 12 in. in nominal inside diameter, with threaded ends and couplings; sizes larger than those shown in the table are measured by the outside diameter and will be furnished with plain ends unless otherwise specified; for such sizes it will be necessary to accept Manufacturers' weights or calculate the weights on the basis of one cubic inch of steel weighing 0.2833 lb.

Ends. 9. Unless otherwise specified, pipe shall conform to the following regular practice:

(*a*) Each end of standard weight welded pipe shall be threaded.

(*b*) Extra strong welded pipe and standard weight and extra strong seamless pipe and all double extra strong pipe shall be furnished with plain ends.

Threads. (*c*) All threads shall be in accordance with the American Standard[1] and cut so as to make a tight joint when the pipe is tested at the mill to the specified internal hydrostatic pressure.

Couplings. (*d*) Each length of threaded pipe shall be provided with one coupling, having clean-cut threads of such a pitch diameter as to make a tight joint. Couplings may be made of wrought iron or steel.

Finish. 10. (*a*) The finished pipe shall be reasonably straight and free from injurious defects. All burrs at the ends of the pipe shall be removed.

(*b*) The zinc coating on galvanized pipe shall be free from injurious defects or excessive roughness.

INSPECTION AND REJECTION

Inspection. 11. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the pipe ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the pipe is being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 12. Each length of pipe which develops injurious defects in shop working or application will be rejected, and the manufacturer shall be notified.

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[1] A complete description of the American Standard Pipe Threads applicable to pipe valves and fittings is contained in the Pipe Thread Bulletin published by the American Engineering Standards Committee.

TENTATIVE SPECIFICATIONS
FOR
LAP-WELDED AND SEAMLESS STEEL PIPE FOR HIGH-TEMPERATURE SERVICE[1]

Serial Designation: A 106 – 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1926; REVISED, 1927, 1928.

Scope. 1. These specifications cover lap-welded and seamless steel pipe for 250, 400, 600, 900 and 1350 lb. per sq. in. pressure and high temperatures (Note 1). Pipe ordered under these specifications shall be suitable for bending, flanging and similar forming operations (Note 2).

MANUFACTURE

Process. 2. (*a*) The steel for lap-welded pipe shall be of soft weldable quality made by the open-hearth process. The steel for seamless pipe may be made by either or both of the following processes: open-hearth or electric-furnace.

(*b*) Welded pipe 2 in. or over in nominal diameter shall be made by the lap-weld process. All pipe $1\frac{1}{2}$ in. or under in nominal diameter shall be made by the seamless process, and may be either hot finished or cold drawn and annealed.

(*c*) Unless otherwise specified, seamless pipe 2 in. or over in nominal diameter shall be furnished hot finished. Upon agreement, cold drawn and annealed pipe may be furnished.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition. 3. (*a*) The steel for welded and seamless pipe shall conform to the following ladle requirements as to chemical composition:

	WELDED	SEAMLESS
Phosphorus, per cent	not over 0.06 (Note 3)	not over 0.04
Sulfur, per cent	" " 0.05	" " 0.05

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. V. H. Lawrence, Secretary of Committee A-1 on Steel, Alan Wood Iron and Steel Co., Conshohocken, Pa.

Check Analysis. (*b*) Analysis may be made by the purchaser from each lot of 500 lengths or less of finished pipe. The phosphorus and sulfur content thus determined shall not exceed that specified in Section 3(*a*) by more than 25 per cent. Drillings for analysis shall be taken from several points around each pipe.

PHYSICAL PROPERTIES AND TESTS

Tension Tests. 4. (*a*) The material shall conform to the following minimum requirements as to tensile properties:

		Seamless	
	Welded	Grade A (Note 2)	Grade B
Tensile strength, lb. per sq. in....	45 000	48 000	62 000
Yield point, lb. per sq. in........	25 000	26 500	35 000
Elongation in 2 in., per cent.....	30	40	25

(*b*) The yield point shall be determined by the drop of the beam of the testing machine, or by other approved methods.

Hydrostatic Tests. 5. Unless otherwise agreed, each length of pipe ordered under these specifications shall be tested at the mill to the hydrostatic test pressures specified in the table below. Welded pipe shall be struck near both ends while under pressure, with a 2-lb. hammer or equivalent.

Class of Pipe, Working Pressure, lb. per sq. in.	Standard Test Pressure, lb. per sq. in.
250	750
400	1000
600	1500
900	2000
1350	3000

Flattening Tests. 6. (*a*) For welded pipe, a section of pipe 6 in. long shall be flattened between parallel plates with the weld located at 90 deg. from the line of direction of the applied force, until opposite walls of the pipe meet. No opening in the weld shall take place until the distance between the plates is two-thirds of the original outside diameter of the pipe. No cracks or breaks in the metal elsewhere than in the lap-weld shall occur until the distance between the plates is one-third of the original outside diameter of the pipe. Evidence of laminations or burnt material shall not develop during the entire flattening process. When double-welded pipe is furnished on special order, the flattening test shall show no opening at the weld until the distance between the plates is one-third of the original outside diameter of the pipe.

(*b*) For Grade A seamless pipe over 2 in. in nominal diameter, a section of pipe not less than 2½ in. long shall be flattened between parallel plates until the distance between the plates is one-third the outside diameter of the pipe, without developing cracks. In no case shall the distance between the plates be less than five times the thickness of the pipe wall.

(*c*) For Grade B seamless pipe over 2 in. in nominal diameter, a section of pipe not less than 2½ in. long shall be flattened between parallel plates until the distance between the plates is one-half the outside diameter of the pipe, without developing cracks. In no case shall the distance between the plates be less than seven times the thickness of the pipe wall.

Bend Tests.

7. For seamless pipe 2 in. in nominal diameter and smaller, a sufficient length of pipe shall stand being bent cold through 90 deg. around a cylindrical mandrel, the diameter of which is twelve times the nominal diameter of the pipe, without developing cracks. When ordered for close coiling, the bend test shall be made 180 deg. around a mandrel which is eight times the diameter of the pipe, without failure.

Test Specimens.

8. (*a*) Test specimens shall consist of sections cut from a pipe. Flattening test specimens shall be smooth on the ends and free from burrs, except when made on "crop" ends taken from welded pipe.

(*b*) Tension test specimens shall be cut longitudinally from the pipe and not flattened. Their widths shall be not less than the wall thickness of the pipe nor more than three times the wall thickness. The sides of specimens shall be parallel between gage marks. If desired, the tension test specimen may consist of full section of the pipe.

Specimens from welded pipe shall be taken at a point approximately 90 deg. from the weld.

(*c*) All specimens shall be tested at room temperature.

Number of Tests.

9. (*a*) From each lot of 500 lengths or less, of each size, two lengths shall be selected for test. Upon one of these the tension test specified in Section 4 shall be made. Upon both of them, the tests specified in Sections 6 (*b*), (*c*) or 7 shall be made.

(*b*) Each length shall be subjected to and withstand the hydrostatic test specified in Section 5.

(*c*) The flattening test described in Section 6 (*a*) shall be made on the crop ends cut from each length of welded pipe.

Retests.

10. (*a*) If the results of any physical or chemical tests of any lot do not conform to the requirements specified in Sections 3, 4, 6, and 7, retests of double the number of additional pipes shall be made, each of which shall conform to the requirements specified.

(*b*) Should a crop end fail in the flattening test, one retest may be made from the failed end.

STANDARD WEIGHTS

Standard Weights. 11. (*a*) The nominal thicknesses for pipe of various diameters shall be specified in the order.

(*b*) Nipples shall be cut from pipe of the same weight and quality as described in these specifications.

Permissible Variations. 12. The weight of the pipe shall not exceed that corresponding to the nominal thickness by more than 5 per cent for the 250, 400, 600 and 900-lb.-per-sq.-in. standards, nor more than 10 per cent for the 1350-lb. standard.

Lengths. 13. Unless otherwise specified, pipe shall be furnished as to lengths in accordance with the following regular practice:

(*a*) The lengths required shall be specified in the order.

(*b*) No jointers are permitted.

WORKMANSHIP AND FINISH

Workmanship. 14. (*a*) For pipe 1½ in. in nominal diameter and smaller, the outside diameter at any point shall not vary more than $\frac{1}{64}$ in. over, nor more than $\frac{1}{32}$ in. under the standard size. For pipe 2 in. in nominal diameter and larger, the outside diameter shall not vary more than one per cent over or under the standard size.

(*b*) The minimum wall thickness at any point for welded, and seamless pipe shall not be more than 12.5 per cent under the nominal wall thickness specified.

Ends. 15. Unless otherwise specified, pipe shall be furnished with plain ends.

Finish. 16. The finished pipe shall be reasonably straight and free from injurious defects. All burrs at the ends of the pipe shall be removed.

MARKING

Marking. 17. Each length of pipe shall be marked with appropriate symbols to show by whom manufactured and that it conforms to these specifications.

INSPECTION AND REJECTION

Inspection. 18. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the pipe ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the pipe is being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment and at the manufacturer's expense, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

19. Each length of pipe which develops injurious defects in shop working or application shall be rejected, and the manufacturer notified. **Rejection.**

EXPLANATORY NOTES

NOTE 1.—This contemplates temperatures from 450 to 750° F. (232 to 400° C.), or at the discretion of the designing engineer, higher temperatures with appropriate pressures may be used. Reference may be made to the dimensional pipe standards for these pressures and temperatures as given in Appendix A to the Tentative American Standard (B 16 *e* - 1927) for Steel Pipe Flanges and Flanged Fittings.

NOTE 2.—Grade A rather than Grade B seamless tubing should be used for cold bending or for fusion or forge welding. The purpose for which pipe is to be used should be stated on the face of the order.

NOTE 3.—The phosphorus limit for the finished pipe is set at 0.06 per cent maximum to permit re-phosphorizing to facilitate welding.

TENTATIVE SPECIFICATIONS
FOR
THE ARBITRATION TEST BAR AND TENSION TEST SPECIMEN FOR CAST IRON[1]

Serial Designation: A 124 - 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1928.

Scope. 1. These specifications cover the arbitration test bar for cast iron, 1.20 in. in diameter, intended for transverse testing placed horizontally upon supports 18 in. apart with a centrally applied load; and the tension test specimen for determining the tensile strength of cast iron. The arbitration test bar represents the metal in the ladle and not in the casting.

ARBITRATION TEST BAR

Mold. 2. The form and dimensions of the pattern and mold for the arbitration test bar shall conform to those shown in Fig. 1. The mold may be made in cores or in dry sand. The bottom of the bar shall be 0.05 in. smaller in diameter than the top, to allow for draft and for the strain of pouring. The pattern shall not be rapped before withdrawing. The flask shall be rammed-up with green molding sand, a little damper than usual, well mixed and put through a No. 8 sieve, with a mixture of 1 to 12 bituminous facing. The mold shall be rammed evenly and fairly hard, thoroughly dried, and not cast until it is cold. The test bar shall not be removed from the mold until cold enough to be handled. It shall not be rumbled or otherwise treated, being simply brushed off before testing.

Pattern. 3. The pattern shall be made of such size that the arbitration test bar will have a diameter of 1.20 in. at the center.

Correction Factors. 4. (*a*) In case the transverse test bar varies from the specified diameter of 1.20 in., a correction factor conforming to the following shall be applied:

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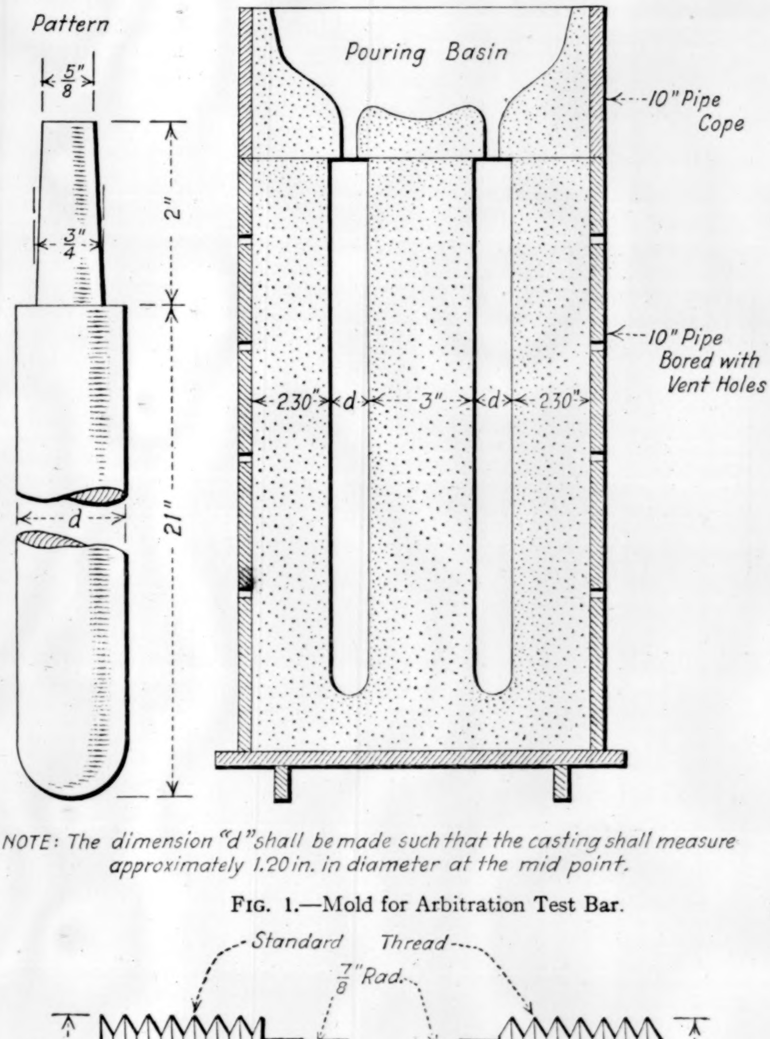
[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. F. B. Coyle, Secretary of Committee A-3 on Cast Iron, 574 Bergen Ave., Jersey City, N. J.


Pattern
5/8"
3/4"
2"
21"
d
Pouring Basin
10" Pipe Cope
10" Pipe Bored with Vent Holes
2.30"
d
3"
d
2.30"

NOTE: The dimension "d" shall be made such that the casting shall measure approximately 1.20 in. in diameter at the mid point.

FIG. 1.—Mold for Arbitration Test Bar.

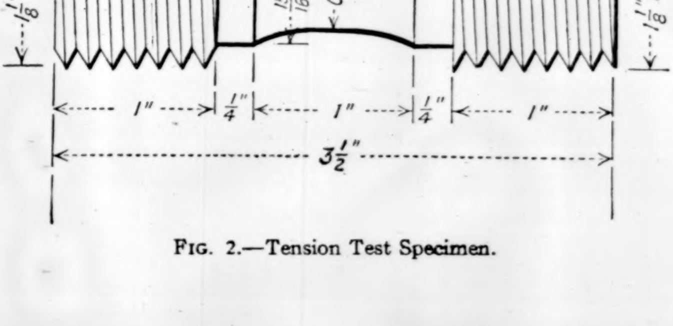

Standard Thread
7/8" Rad.
1 1/8" Diameter
15/16" Diam.
0.8" Diam.
1 1/8" Diameter
1"
1/4"
1"
1/4"
1"
3 1/2"

FIG. 2.—Tension Test Specimen.

Diameter of Arbitration Test Bar, in.	Correction Factor	Diameter of Arbitration Test Bar, in.	Correction Factor
1.10	0.770	1.21	1.025
1.11	0.791	1.22	1.051
1.12	0.813	1.23	1.077
1.13	0.835	1.24	1.103
1.14	0.857	1.25	1.130
1.15	0.880	1.26	1.158
1.16	0.903	1.27	1.185
1.17	0.927	1.28	1.214
1.18	0.951	1.29	1.242
1.19	0.975	1.30	1.271
1.20	1.000		

If the test bar is not round the correction factor cannot be obtained from the preceding table and shall be calculated as follows: square the depth of the bar measured at point of application of load, multiply by the width and divide the product by 1.728.

(*b*) In order to correct to a diameter of 1.20 in. the breaking load obtained in testing, the bar shall be divided by the correction factor.

TENSION TEST SPECIMEN

Tension Test Specimen.

5. The tension test specimen shall be machined from one of the broken pieces of the arbitration test bar, and shall conform to the dimensions shown in Fig. 2.

TENTATIVE SPECIFICATIONS
FOR
ZINC-COATED (GALVANIZED) BARB WIRE[1]

Serial Designation: A 121 – 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1928.

Scope. 1. These specifications cover zinc-coated barb wire in which the wire is coated before or after fabrication, as herein noted. The weight classification and all test procedure shall be in accordance with the Tentative Methods of Testing Zinc-Coated (Galvanized) Iron and Steel Wire and Wire Products (Serial Designation: A 110 – 27 T) of the American Society for Testing Materials.[2]

2. These specifications cover the usual sizes and standard constructions of barb wire as follows:

NOMINAL DIAMETER OF WIRE IN THE STRAND, IN.	SIZE, STEEL WIRE GAGE	COMMERCIAL DESIGNATION	NUMBER OF BARBS	BARB SPACING, IN.
0.105	12	Hog	4	4
0.105	12	Cattle	4	6
0.098	12½	Hog	4	4
0.098	12½	Cattle	4	4
0.098	12½	Hog	2	3
0.098	12½	Cattle	2	5
0.080	14	Hog	2	3
0.080	14	Cattle	2	5

MANUFACTURE

Zinc Coating. 3. The zinc used for the coating shall be any grade of zinc conforming to the requirements of the Standard Specifications for Slab Zinc (Spelter) (Serial Designation: B 6) of the American Society for Testing Materials.[3]

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. James Aston, Secretary of Committee A-5 on Corrosion of Iron and Steel, Department of Mining and Metallurgy, Carnegie Institute of Technology, Pittsburgh, Pa.

[2] *Proceedings,* Am. Soc. Testing Mats., Vol. 27, Part I, p. 696 (1927); also 1928 Book of A.S.T.M. Tentative Standards, p. 110.

[3] 1927 Book of A.S.T.M. Standards, Part I, p. 524.

Base Metal.

4. The base metal of the barb wire shall be of a good commercial quality of steel or iron wire. If copper is desired, the copper content shall not be less than 0.2 per cent.

WEIGHT AND UNIFORMITY OF COATING

Tests of Coating.

5. The weight and uniformity of the coating shall be defined and tested in accordance with the Tentative Methods of Testing Zinc-Coated (Galvanized) Iron and Steel Wire and Wire Products (Serial Designation: A 110 – 27 T) of the American Society for Testing Materials.[1]

Weight and Uniformity of Coating.

6. The weight and uniformity of the coating for the various gages of wire composing the barb wire shall be as specified by the purchaser and in accordance with the weights and dips designated in Table I.

Table I.—Commercially Available Zinc-Coated Barb Wire.

Size, Steel Wire Gage	Nominal Diameter of Strand Wire, in.	Class Designation		
		Wt. 5 Dip 3	Wt. 3½ Dip 2	Wt. 2 Dip 1
12	0.105	✓	✓	..
12½	0.098	✓	✓	..
14	0.080	..	✓	✓

Note.—Sizes in which any given weight of coating may be regularly obtained in the open market are indicated by a ✓ opposite the gage in the above table.

For special purposes, barb wire galvanized after weaving is available in the above and larger sizes with a coating of Wt. 10, Dip 4.

For special purposes, barb wire galvanized before weaving may be obtained in larger sizes, carrying heavier coatings than indicated in the above table.

SIZE AND PERMISSIBLE VARIATIONS

Size.

7. (*a*) The size of the finished wire shall be expressed as the nominal diameter of the wire in decimal fractions of an inch.

Permissible Variations.

(*b*) The permissible variations from the nominal diameter in barb wire galvanized before weaving shall be ±0.005 in.

PACKING AND MARKING

Packing and Marking.

8. Each spool of barb wire shall be compactly wound and fastened and shall be legibly marked in accordance with the specifications of the purchaser.

INSPECTION, SAMPLING AND REJECTION

Inspection.

9. The manufacturer shall afford the inspector representing the purchaser, without charge, all reasonable facilities to satisfy him

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 696 (1927); also 1928 Book of A.S.T.M. Tentative Standards, p. 110.

that the material is being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture, prior to shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Billing. 10. All spools of barb wire accepted by the purchaser shall be billed to him on the basis of the original weight or footage of the spools before sampling.

Sampling. 11. (*a*) For purpose of tests, one spool shall be selected at random from every ten spools or fraction thereof in a shipment. Sufficient length of barb wire shall be cut from the end of the reel to include three barbs.

(*b*) In the case of barb wire galvanized before weaving, the barbs shall be cut from the strand and discarded. The strand wires shall be tested separately.

(*c*) Barb wire galvanized after weaving shall be tested as woven with barbs and strand in place.

Rejection. 12. If 20 per cent of the samples tested fail to conform to the requirements of these specifications, then a check test of these same sample spools shall be made and, if in the check test 20 per cent of the samples fail to conform to the requirements, then the entire lot represented by the samples may be rejected.

TENTATIVE SPECIFICATIONS
FOR
ZINC-COATED (GALVANIZED) STEEL WIRE STRAND[1]

Serial Designation: A 122 - 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1928.

Scope. 1. These specifications cover zinc-coated steel wire strand composed of a multiplicity of wires and suitable for use as guy wires, messenger wires, span wires, etc. The weight classification and all test procedure shall be in accordance with the Tentative Methods of Testing Zinc-Coated (Galvanized) Iron and Steel Wire and Wire Products (Serial Designation: A 110 - 27 T) of the American Society for Testing Materials.[2]

MANUFACTURE

Zinc Coating. 2. The zinc used for the coating shall be any grade of zinc conforming to the requirements of the Standard Specifications for Slab Zinc (Spelter) (Serial Designation: B 6) of the American Society for Testing Materials.[3]

Base Metal. 3. The base metal shall be iron or steel of such quality and purity that, when drawn and galvanized to the size of wire specified, the finished strand will have the properties and characteristics herein specified.

WEIGHT AND UNIFORMITY OF COATING

Tests of Coating. 4. The weight and uniformity of the coating shall be defined and tested in accordance with the requirements of the Tentative Methods of Testing Zinc-Coated (Galvanized) Iron and Steel Wire and Wire Products (Serial Designation: A 110 - 27 T) of the American Society for Testing Materials.[2]

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. James Aston, Secretary of Committee A-5 on Corrosion of Iron and Steel, Department of Mining and Metallurgy, Carnegie Institute of Technology, Pittsburgh, Pa.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 696 (1927); also 1928 Book of A.S.T.M. Tentative Standards, p. 110.

[3] 1927 Book of A.S.T.M. Standards, Part I, p. 524.

TABLE I.—COMMERCIALLY AVAILABLE ZINC-COATED STEEL WIRE STRAND.

Nominal Diameter of Wire in the Strand, in.	"Galvanized" Common			"Extra or Double Galvanized" Common, Siemens-Martin, High Strength, and Extra-High Strength				
	Wt. 5 Dip 3	Wt. 3.5 Dip 2	Wt. 1.5 Dip 1	Wt. 9 Dip 4	Wt. 8 Dip 4	Wt. 7 Dip 3	Wt. 6 Dip 3	Wt. 5 Dip 2.5
0.207	✓	..	..	✓	..	..	..	..
0.188	✓	..	..	✓	..	..	..	..
0.165	✓	..	..	..	✓	..	..	..
0.145	✓	..	..	..	✓	..	..	..
0.125	..	✓	..	..	✓	..	..	..
0.104	..	✓	..	..	..	✓	..	..
0.093	..	✓	..	..	..	✓	..	..
0.080	..	✓	..	..	..	..	✓	..
0.072	..	..	✓	..	..	..	✓	..
0.062	..	..	✓	..	..	..	✓	..
0.052	..	..	✓	..	..	..	..	✓
0.041	..	..	✓	..	..	..	...	✓

NOTE.—Sizes in which any given weight of coating may be regularly obtained in the open market are indicated by a ✓ opposite the nominal diameter in the above table.

For intermediate sizes of wire in the strand the Weight and Dip designations are the same as for the next finer size shown in above table.

TABLE II.—PHYSICAL PROPERTIES OF ZINC-COATED STEEL WIRE STRAND.

Approximate Diameter of the Strand	Number of Wires in Strand	Diameter of Wires in Strand	Weight of Strand per 1000 ft., lb.	Minimum Breaking Strength, lb.			
				Common	Siemens-Martin	High Strength	Extra-High Strength
$\frac{1}{8}$	7	0.041	31.8	540	910	1 330	1 830
$\frac{5}{32}$	7	0.052	51.3	870	1 470	2 140	2 940
$\frac{3}{16}$	7	0.062	72.9	1 150	1 900	2 850	3 990
$\frac{7}{32}$	7	0.072	98.3	1 540	2 560	3 850	5 400
$\frac{1}{4}$	7	0.080	121	1 900	3 150	4 750	6 650
$\frac{9}{32}$	7	0.093	164	2 570	4 250	6 400	8 950
$\frac{5}{16}$	7	0.104	205	3 200	5 350	8 000	11 200
$\frac{3}{8}$	7	0.125	296	4 250	6 950	10 800	15 400
$\frac{7}{16}$	7	0.145	399	5 700	9 350	14 500	20 800
$\frac{1}{2}$	7	0.165	517	7 400	12 100	18 800	26 900
$\frac{1}{2}$	19	0.100	504	7 620	12 700	19 100	26 700
$\frac{9}{16}$	7	0.188	671	9 600	15 700	24 500	35 000
$\frac{9}{16}$	19	0.113	637	9 640	16 100	24 100	33 700
$\frac{5}{8}$	7	0.207	813	11 600	19 100	29 600	42 400
$\frac{5}{8}$	19	0.125	796	11 000	18 100	28 100	40 200
$\frac{3}{4}$	19	0.150	1155	16 000	26 200	40 800	58 300
$\frac{7}{8}$	19	0.177	1581	21 900	35 900	55 800	79 700
1	19	0.200	2073	28 700	47 000	73 200	104 500
1	37	0.143	2057	28 300	46 200	71 900	102 700
$1\frac{1}{8}$	37	0.161	2691	36 000	58 900	91 600	130 800
$1\frac{1}{4}$	37	0.179	3248	44 600	73 000	113 600	162 200

Weight and Uniformity of Coating.

5. The weight and uniformity of the coating of the various sizes of wire composing the strand shall be as specified by the purchaser and in accordance with the weights and dips designated in Table I. Commercial strand designated as Common strand is available in two weights of coating known as "Galvanized" and "Extra or Double Galvanized." Strand designated as Siemens-Martin, High Strength and Extra-High Strength is furnished and used in one weight of coating only, namely, that which is ordinarily known as "Extra Galvanized" or "Double Galvanized."

PHYSICAL PROPERTIES AND TESTS

Physical Properties.

6. The number of wires in a strand, the size of the component wires, the weight per 1000 feet of strand, and the minimum breaking strength shall conform to the values specified in Table II.

Elongation.

7. The elongation of the strand in 24 in. shall not be less than the following:

Common Strand	10 per cent
Siemens-Martin	8 "
High Strength	5 "
Extra-High Strength	4 "

SIZE AND PERMISSIBLE VARIATIONS

Size.

8. (*a*) The size of the finished strand shall be expressed as the diameter of the wire in fractions of an inch.

Permissible Variations.

(*b*) The permissible variations from the diameter of the strand shall be:

For strand, $\frac{5}{8}$ in. and over in diameter	±0.030 in.
For strand, $\frac{1}{4}$ to $\frac{9}{16}$ in., inclusive, in diameter	±0.020 in.
For strand, $\frac{1}{8}$ to $\frac{7}{32}$ in., inclusive, in diameter	±0.010 in.

WORKMANSHIP AND FINISH

Surface Finish.

9. (*a*) The wire shall be free from splints, scales, inequalities, flaws, and other imperfections not consistent with good commercial practice.

Coating.

(*b*) The zinc coating shall be smooth and continuous.

PACKING AND MARKING

Packing and Marking.

10. Strand wire shall be furnished in lengths as specified and in compact coils or on reels, and shall be well protected against mechanical injury in shipping as agreed upon at the time of placing the order.

INSPECTION, SAMPLING AND REJECTION

Inspection.

11. The manufacturer shall afford the inspector representing the purchaser, without charge, suitable facilities and equipment for making

the tests required by these specifications, in order that he may satisfy himself that the material is being furnished in accordance with these specifications. Unless otherwise agreed upon, all tests and inspection shall be made at the place of manufacture, prior to shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Sampling.

12. For purpose of tests, a sample shall be taken from each reel or coil when the quantity of reels or coils does not exceed three. On larger quantities, samples for test shall be taken from 10 per cent of the lot.

TENTATIVE SPECIFICATIONS
FOR
ZINC (HOT-GALVANIZED) COATINGS ON STRUCTURAL STEEL SHAPES, PLATES AND BARS AND THEIR PRODUCTS[1]

Serial Designation: A 123 – 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1928.

Scope. 1. These specifications cover the protective zinc coatings, applied on structural steel shapes, plates and bars and their products (Note 1) by dipping the articles in a molten bath of zinc (Note 2).

NOTE.—The structural steel mentioned in these specifications is defined by the Standard Specifications for Structural Steel for Bridges (Serial Designation: A 7), for Structural Steel for Buildings (Serial Designation: A 9), for Structural Steel for Ships (Serial Designation: A 12) of the American Society for Testing Materials,[1] and the Association of American Steel Manufacturers' Standard Specifications for Class A and Class B steels.

CHEMICAL PROPERTIES

Slab Zinc. 2. The slab zinc used for the coating shall conform to the requirements of the Standard Specifications for Slab Zinc (Spelter) (Serial Designation: B 6) of the American Society for Testing Materials,[2] and shall be at least equal to the grade designated as "Prime Western."

Chemical Composition. 3. (*a*) The impurities contained in the molten zinc bath during actual operation as shown by ladle analysis shall not exceed the following:

Lead	1.60 per cent
Iron	0.08 "
Aluminum	0.01 "

Samples for Chemical Analysis. 4. (*a*) Analysis of the ladle tests shall be based on the combined borings from not less than three samples taken on the center line of the pot. One sample shall be taken midway of the pot and the other two at opposite ends, but not nearer the ends than one-half the width of the pot. The samples shall be taken from a depth of at least 2 in. below the surface of the zinc but not greater than 25 per cent of the depth of the zinc.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. S. S. Tuthill, Secretary of Sectional Committee on Zinc Coating of Iron and Steel, functioning under the procedure of the American Engineering Standards Committee, American Zinc Institute, Inc., 27 Cedar St., New York City.

[2] 1927 Book of A.S.T.M. Standards, Part I, p. 524.

(*b*) The implements and molds used to obtain the samples shall be of such materials as shall not change the proportions of lead, iron or aluminum in the zinc sample.

PHYSICAL PROPERTIES AND TESTS

Steel Embrittlement. 5. In so far as possible the processes of pickling and zinc coating shall not cause the embrittlement of the base material nor change its physical or chemical characteristics (Note 3).

Weight of Coating. 6. The weight of the zinc coating per square foot of surface shall not average less than 2.0 oz., and no individual specimen in any one shift shall show less than 1.8 oz.

Test Specimens. 7. (*a*) Test specimens shall preferably be selected from the material being galvanized and shall be galvanized at the same time, in the same manner and in the same pot as the material whose properties they are intended to indicate. If the lot of material is of inconvenient lengths, pieces of the same shape but of convenient lengths for handling may be substituted as test specimens (Note 4).

(*b*) Three specimens may be required as needed for carrying out, as described in Section 14 (*b*), the determination of the weight of coating on material galvanized in one shift.

(*c*) No test specimen shall be used for the determination of the weight of coating which would fail to conform to other requirements of these specifications as described in Sections 10, 11 and 14 (*a*).

Procedure. 8. The weight of the zinc coating shall preferably be determined by weighing one or more specimens after pickling and drying and again after coating, or by weighing coated specimens, stripping them in hydrochloric acid and again weighing them after stripping and drying.

Uniformity of Coating. 9. In the absence of a practicable test to determine the uniformity of coating on structural materials the uniformity of the zinc coating shall be determined by visual inspection in accordance with Section 10.

WORKMANSHIP AND FINISH

Finish and Tightness. 10. The zinc coating shall be continuous and thorough. It shall not scale or blister or be removable by any reasonable process of handling or erection. The coating shall be free from hair-line cracks, holes, so called "acid spots," black or uncoated spots. The surface of the coating shall be reasonably smooth and free from objectionable lumps or globules of zinc and shall be free from all indications of dross (Note 5) and objectionable flux or other impurities. The coating shall not interfere with the intended use of the material.

Bare Area. 11. For an article having no dimension greater than one foot the limit of the total bare area shall be 0.02 per cent of its galvanized surface; but the limiting size of any individual bare spot shall be $\frac{1}{16}$ in. in diameter or the equivalent in area. "Bare area" shall be considered as that area requiring protection by galvanizing but not actually so protected.

Handling. 12. After immersion, the structural shapes, plates or bars shall not be subjected to any process of scraping or wiping which will reduce the uniformity or weight of the zinc coating.

INSPECTION AND REJECTION

Inspection. 13. (*a*) The inspector representing the purchaser shall have free entry at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the coating is being furnished in accordance with these specifications.

(*b*) The material shall be inspected at the manufacturer's plant during the process of manufacture. However, by agreement the purchaser may make the tests which govern the acceptance or rejection of the materials in his own laboratory or elsewhere; such tests shall be made at the expense of the purchaser.

Rejection. 14. (*a*) Visual inspection of materials ready for shipment shall be made to determine conformity with the requirements of Section 10; when partial inspection warrants rejection of a lot, the manufacturer may re-sort the lot and submit it once again for inspection.

(*b*) Where tested in accordance with Sections 7 and 8, if one specimen should fail to conform to the requirements specified in Section 6 for the weight of coating, a second and third specimen shall be tested. Failure of either the second or third specimen to conform to the requirements shall be cause for rejection of the lot which the samples represent.

(*c*) Materials that have been rejected may be re-galvanized and again submitted for test and inspection when they shall conform to the requirements of these specifications.

EXPLANATORY NOTES

NOTE 1.—The use of the word "products" is not meant to imply an unqualified indorsement of the indiscriminate practice of applying zinc coatings on assembled parts.

NOTE 2.—The zinc coating on the materials covered by these specifications is too heavy to permit bending and other severe fabrication of the galvanized article without seriously damaging the coating.

NOTE 3.—In isolated cases steels are encountered which are susceptible to embrittlement by the normal hot-dip galvanizing processes. Such embrittlement may depend on the chemical composition or a process of cold working the material in fabrication. Proper heat treatment to correct embrittlement should be covered by separate contract between the purchaser and the manufacturer.

NOTE 4.—The use of convenient lengths of material for test specimens should not be interpreted to mean that small pieces of flat plate or odd shapes can be used as test specimens in place of structural shapes. Practice has shown that such coupon specimens do not give true indications of the weight of coating on the shapes.

NOTE 5.—It is highly desirable but not always practicable to keep the materials being coated from coming in contact with the dross, but so far as practicable such contact should be avoided. Every practice tending to agitate the dross should be avoided.

PROPOSED SPECIFICATIONS
FOR
THE ZINC COATING ON IRON AND STEEL SHEETS[1]

Scope. 1. These specifications cover five classes of zinc coatings for iron and steel sheets, applied by the hot-dip process, as follows:

Class A.—Extra heavily coated sheets that are not intended to be formed other than by corrugating.

Class B.—Heavily coated sheets that are not intended to be formed other than by corrugating and curving to large radii.

Class C.—Moderately heavily coated sheets for moderate bending.

Class D.—Ordinary coated sheets for general utility. These coatings approximate those of Class C except in medium gages in which coatings of Class D are appreciably lighter. Class D represents material generally available in warehouse stocks, which is not intended for use where relatively long life, represented by Classes A, B and C, or severe forming, represented by Class E, is required.

Class E.—Sheets having lighter, more tightly adherent coatings to reduce liability of flaking in severe forming. The sheet maker should be made acquainted with the requirements of fabrication.

PHYSICAL PROPERTIES AND TESTS

Weight of Coating. 2. (*a*) The weight of the zinc coating shall conform to the requirements specified in Tables I and II. The weight of coating is the total coating, expressed in ounces, on both sides of a sheet 1 ft. square.

(*b*) The weight test is to be preferred and shall consist of a 10-sheet lot of a light gage or a 5-sheet lot of No. 16 gage or heavier. The test lots shall be weighed after pickling, washing and drying, and again after coating, and the weight of coating calculated from the difference on the basis of the ordered size. The scale used shall be sensitive to ½ lb. The average of weight tests shall be determined from not less than ten successive weight tests that have met the requirements of the specification as provided in Section 5 (*a*).

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[1] These proposed specifications were developed by the Sectional Committee on Zinc Coating of Iron and Steel, functioning under the procedure of the American Engineering Standards Committee Criticisms of these proposed specifications are solicited and should be directed to Mr. S. S. Tuthill, Secretary of the Sectional Committee, American Zinc Institute, Inc., 27 Cedar St., New York City.

Requirements of these specifications are excerpted from the Standard Specifications for Zinc Coated (Galvanized) Sheets (Serial Designation: A 93) of the American Society for Testing Materials (1927 Book of A.S.T.M. Standards, Part I, p. 270), and include the following Sections from those specifications: Sections 1, 4, 5 (*b*), 6, 7, 10, 11, 12, 13 and 14.

(*c*) The triple spot test shall consist of the average of determinations from the three specimens cut from the test sheet as provided in Sections 4 and 5 (*b*). The average of triple spot tests shall be determined from not less than ten successive triple spot tests and shall include all such tests made.

TABLE I.—DESIRED OR ORDERED WEIGHT OF COATINGS, OZ. PER SQ. FT.

GALVANIZED SHEET GAGE	CLASS A	CLASS B	CLASS C	CLASS D	CLASS E
No. 8......	2.75	2.50	2.00	No specified coatings, see Section 1	No specified coatings, see Section 1
No. 9......	2.75	2.50	2.00		
No. 10......	2.75	2.50	2.00		
No. 11......	2.75	2.50	2.00		
No. 12......	2.75	2.50	2.00		
No. 13......	2.75	2.50	2.00		
No. 14......	2.75	2.50	2.00		
No. 16......	2.75	2.50	2.00		
No. 18......	2.75	2.50	1.75		
No. 20......	2.75	2.50	1.75		
No. 22......	2.75	2.50	1.75		
No. 24......	....	2.50	1.50		
No. 26......	....	2.25	1.25		
No. 27......	....	2.00	1.25		
No. 28......	....	1.75	1.25		
No. 29......	....	1.50	1.25		
No. 30......	....	1.25	1.25		

TABLE II.—MINIMUM WEIGHT-OF-COATING TEST LIMITS, OZ. PER SQ. FT.

Class According to Desired or Ordered Coating	Rejection Limits by Different Tests[a]					
	Average of Weight Tests	Any One Weight Test	Average of Triple Spot Tests	Any One Triple Spot Test	Average of Minimum Spot Tests	Any One Minimum Spot Test
2.75	2.60	2.45	2.40	2.30	2.20	2.00
2.50	2.30	2.20	2.15	2.00	1.95	1.80
2.25	2.10	2.00	1.95	1.80	1.75	1.60
2.00	1.90	1.80	1.75	1.60	1.55	1.40
1.75	1.65	1.55	1.50	1.35	1.30	1.20
1.50	1.40	1.30	1.25	1.15	1.10	1.00
1.25	1.15	1.10	1.05	0.95	0.90	0.85

[a] Different methods of sampling and testing give different results as indicated in the above table. The purchaser shall specify which method he will use.

The minimum spot test shall be that one of the three specimens of the triple spot test bearing the lightest coating, or the purchaser may select a single specimen taken from any part of the sheet, at least 2 in. from the side and 4 in. from the end. The average of minimum spot tests shall be determined from not less than ten successive minimum spot tests and shall include all such tests made.

(*d*) The weight of the zinc coating by triple and minimum spot tests shall be determined by the hydrochloric acid - antimony chloride, or sulfuric - permanganate method as described in the Standard Methods of Determining Weight of Coating on Zinc-Coated Articles (Serial Designation: A 90) of the American Society for Testing Materials.[1] The weight of coating, in ounces per square foot, is numerically equal to that determined in grams from a sample $2\frac{1}{4}$ in. square.

Coating Tests. 3. Sheets of Class A of No. 18 gage and lighter shall stand corrugating without flaking of the coating. Sheets of Class B of No. 12 gage and lighter shall stand corrugating and also subsequent longitudinal curving, as given below, without flaking of the coating. The corrugations for these tests shall not be less than $2\frac{2}{3}$ in. in width and not more than $\frac{1}{2}$ in. in depth.

GALVANIZED SHEET GAGE	DIAMETER OF CIRCLE
No. 12	36 in.
No. 14	24 "
No. 16	18 "

In the case of sheets of Class C, any part of the test specimen specified in Section 4, of sheets lighter than No. 16 gage, shall stand being bent in any direction without flaking of the coating on either side when bent through 180 deg. over four thicknesses of the material. A vise with smooth jaws and operated by hand shall be used for making the bend tests.

Test Specimens. 4. For the triple and minimum spot tests, three specimens exactly $2\frac{1}{4}$ in. square shall be cut from each test sheet, one being cut from the center and the others from diagonally opposite corners, but at least 4 in. from the end and 2 in. from the side. The bend test specimens shall be cut from the test sheet at least 4 in. from the end and 2 in. from the side. These specimens, so far as practicable, shall be cut from sheets that are imperfect outside the zone from which the specimens are to be taken.

Number of Tests. 5. (*a*) Weight tests shall be made of not less than 1 per cent of the sheets of each gage and ordered coating, or at approximately hourly intervals. If an inspector representing the purchaser witnesses and accepts weight tests, the triple and minimum spot tests shall not be made. If certificate of weight tests be accepted, the triple and minimum spot tests shall not be made unless doubt arises regarding uniformity of the material.

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[1] 1927 Book of A.S.T.M. Standards, Part I, p. 343.

(*b*) The bend and spot tests, if required, shall be made from one sheet in each lot of 1000 sheets or fraction thereof, of each gage and ordered coating.

(*c*) If any sheet fails to meet the requirements of these specifications, a retest shall be made from two other sheets in the same lot, both of which shall meet the requirements.

FINISH

6. The finished sheets shall be of first-class commercial quality, free from injurious defects, such as blisters, flux and uncoated spots. **Finish.**

MARKING

7. The top sheet of each bundle or the top sheet of a number of sheets when shipped loose, shall show legibly the name and brand of the manufacturer, class, gage, and size, unless otherwise ordered. **Marking.**

INSPECTION AND REJECTION

8. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except triple and minimum spot tests) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works. **Inspection.**

9. Sheets represented by samples which fail to conform to the requirements of these specifications will be rejected and the manufacturer shall be notified. **Rejection.**

10. Samples tested in accordance with Section 5 (*b*), which represent rejected material, shall be preserved for two weeks from the date of the test report. **Rehearing.**

TENTATIVE METHODS OF SAMPLING ROLLED AND FORGED STEEL PRODUCTS FOR CHECK ANALYSIS[1]

Serial Designation: A 33 - 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1928.

SAMPLING

Different parts of a piece of steel vary in composition. For this reason, a sample from a single piece must be carefully selected if it is to be representative of that piece. If the analysis is to be representative of the melt, a number of representative pieces should be sampled and analyzed separately. In any case, the sample should be so selected as to be thoroughly representative, and large enough to suffice for all of the required determinations.

It should be remembered that the composition of the steel is changed by certain operations and that samples should be taken from the steel in its original condition.

PREPARATION OF SAMPLES

Samples shall consist of drillings or chips cut by some machine tool without the application of water, oil, or other lubricant, and shall be free from scale, surface metal, grease, dirt, or other foreign substances. If the samples are taken by drilling, a drill not less than $\frac{1}{2}$ nor more than $\frac{3}{4}$ in. in diameter shall be used. Samples shall be uniform, thoroughly mixed, and free from dust. Chips too coarse to pass a No. 20 sieve are not recommended, nor shall long curly drillings which will not pack closely for the carbon determination be used.

In referring samples to other analysts for check analyses, pieces of the original full-size section, when possible, should be submitted rather than cuttings, unless the latter are specifically requested.

LOCATION OF SAMPLES

Large Sections.—For large sections, including blooms, billets, slabs, rounds, squares, shapes, etc., samples shall be taken at any point midway between the outside and the center of the piece by drilling parallel to the axis. In cases where this is not practicable, the piece shall be drilled on the side, see Figs. 1, (*b*) and (*c*), but the drillings shall not be collected until they represent the portion midway between the outside and the center. The tension test specimen may be used for sampling if it conforms to the above conditions.

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[1] Criticisms of these Tentative Methods are solicited and should be directed to Mr. V. H. Lawrence, Secretary of Committee A-1 on Steel, Alan Wood Iron and Steel Co., Conshohocken, Pa.

These methods, when adopted as standard, will be added to the present Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial Designation: A 33 - 24), 1927 Book of A.S.T.M. Standards, Part I, p. 276.

Bored Forgings.—For bored forgings, samples shall be taken midway between the inner and outer surface of the wall.

Thin Material.—For thin material or material of small cross-section, such as plates, shapes, bars, etc., if the method described above for large sections is not applicable, the sample shall be taken by machining off the entire cross-section or, if this is not possible, by drilling entirely through the material at a point midway between the outside and the center, see Fig. 1 (*a*).

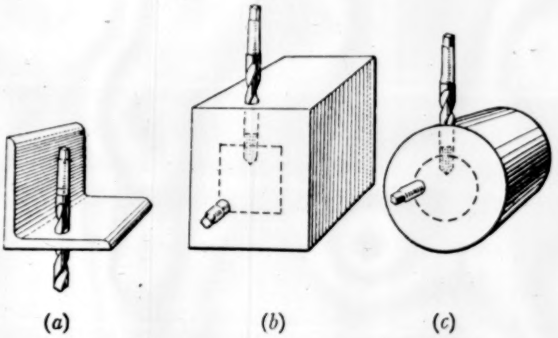
(*a*) (*b*) (*c*)

FIG. 1.—Location of Samples for Check Analysis.

Sheets Rolled Longitudinally.—For sheets rolled from slabs or bars longitudinally, the specimen for sampling shall be cut 2 in. in width and across the full width of the sheet as rolled. The specimen shall be cleaned by pickling or grinding and then folded once or more by bringing the ends together and closing the bend. The sample for analysis shall be taken in the middle of this length by milling the inside sheared edges or drilling entirely through from the flat surface. Sampling by milling is preferable. For sheets of a light gage more than one specimen may be taken and stacked together before folding.

Sheets Rolled Transversely.—For sheets rolled from slabs or bars transversely, the specimen shall be cut from the side of the sheet, half way between the middle and end as rolled, 2 in. in width and 18 in. in length. If the sheet is No. 20 gage (24 oz. per sq. ft. or 0.037 in. in thickness) or lighter, the specimen shall be cut from the full length of the sheet as rolled. The specimen selected shall be cleaned by pickling or grinding and then folded once or more by bringing the ends together and closing the bend. The sample for analysis shall be taken in the middle of this length by milling the inside sheared edges or drilling entirely through from the flat surface. Sampling by milling is preferable.

Sheets Not of the Full Size Rolled.—Sheets cut from larger sheets and not of the full size rolled shall be sampled by milling or drilling the sheet in a sufficient number of places so that the sample is representative of the entire sheet. The sampling may be facilitated by folding the sheet both ways.

TENTATIVE DEFINITIONS OF TERMS RELATING TO HEAT TREATMENT OPERATIONS (ESPECIALLY AS RELATED TO FERROUS ALLOYS)[1]

Serial Designation: A 119 – 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

Issued, 1927; Revised, 1928.

In preparing the definitions included herein, the terms have been so defined, as most in keeping with present day usage, that they shall mean definite operations and shall not be considered as referring to the resultant structures or general conditions.

By "critical temperature range," as used in the definitions, is meant that temperature range illustrated by the following Fig. 1, taken from Howe:

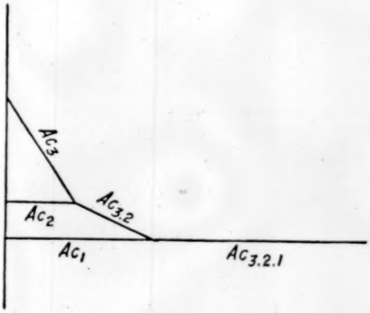

Fig. 1.

Heat Treatment.—An operation or combination of operations involving the heating and cooling of a metal or an alloy in the solid state.

Note.—This is for the purpose of obtaining certain desirable conditions or properties. Heating and cooling for the sole purpose of mechanical working are excluded from the meaning of this definition.

Quenching.—Immersing to cool.

Note.—Immersion may be in liquids, gases or solids.

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[1] Criticisms of these Tentative Definitions are solicited and should be directed to Mr. J. H. Hall, Secretary of Committee A-4 on Heat Treatment of Iron and Steel, Taylor-Wharton Iron and Steel Co., High Bridge, N. J.

Hardening.—Heating and quenching certain iron-base alloys from a temperature either within or above the critical temperature range.

Annealing.—Annealing is a heating and cooling operation of a material in the solid state.

NOTE 1.—Annealing usually implies a relatively slow cooling.

NOTE 2.—Annealing is a comprehensive term. The purpose of such a heat treatment may be:

(*a*) To remove stresses
(*b*) To induce softness
(*c*) To alter ductility, toughness, electrical, magnetic or other physical properties
(*d*) To refine the crystallin structure
(*e*) To remove gases

In annealing, the temperature of the operation and the rate of cooling depend upon the material being heat treated and the *purpose* of the treatment.

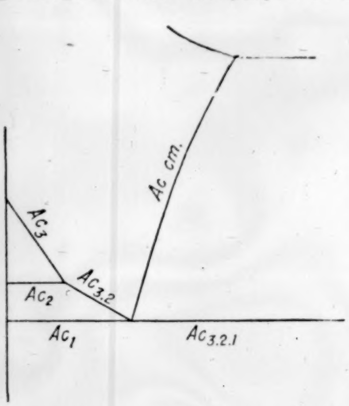

FIG. 2.

Certain specific heat treatments coming under the comprehensive term "annealing" are:

(*a*) *Full Annealing*.—Heating iron-base alloys above the critical temperature range, holding above that range for a proper period of time followed by slow cooling through the range.

NOTE.—The annealing temperature is generally about 100° F. (55° C.) above the upper limit of the critical temperature range, and the time of holding is usually not less than one hour for each inch of section of the heaviest objects being treated. The objects being treated are ordinarily allowed to cool slowly in the furnace. They may, however, be removed from the furnace, and cooled in some medium which will prolong the time of cooling as compared to unrestricted cooling in the air.

(*b*) *Process Annealing*.—Heating iron-base alloys to a temperature below or close to the lower limit of the critical range followed by cooling as desired.

NOTE.—This heat treatment is commonly applied in the sheet and wire industries and the temperatures generally used are from 1020 to 1200° F. (550 to 650° C.).

(c) *Normalizing.*—Heating iron-base alloys above the critical temperature range followed by cooling to below that range in still air at ordinary temperature.

NOTE.—In the case of hyper-eutectoid steel, it is often desirable to heat above the Ac_{cm} line, as shown in Fig. 2.

(d) *Patenting.*—Heating iron-base alloys above the critical temperature range followed by cooling to below that range in molten lead maintained at a temperature of about 700° F. (365° C.).

NOTE.—This treatment is usually applied in the wire industry either as a finishing treatment or especially in the case of eutectoid steel as a treatment previous to further wire drawing. Its purpose is to produce a sorbitic structure.

(e) *Spheroidizing.*—Prolonged heating of iron-base alloys at a temperature in the neighborhood of, but generally slightly below, the critical temperature range, usually followed by relatively slow cooling.

NOTE 1.—In the case of small objects of high-carbon steels, the spheroidizing result is achieved more rapidly by prolonged heating to temperatures alternately within and slightly below the critical temperature range.

NOTE 2.—The object of this heat treatment is to produce a globular condition of the carbide.

(f) *Tempering (also termed Drawing).*—Reheating after hardening, to some temperature below the critical temperature range followed by any rate of cooling.

NOTE 1.—Although the terms "tempering" and "drawing" are practically synonymous as used in commercial practice, the term "tempering" is preferred.

NOTE 2.—Tempering meaning the operation of hardening followed by reheating is a usage which is illogical and confusing in the present state of the art of heat treating and should be discouraged.

(g) *Malleablizing.*—Malleablizing is a type of annealing operation with slow cooling whereby combined carbon in white cast iron is transformed to temper carbon and in some cases the carbon is entirely removed from the iron.

NOTE.—Temper carbon is free carbon in the form of rounded nodules made up of an aggregate of minute crystals.

(h) *Graphitizing.*—Graphitizing is a type of annealing of cast iron whereby some or all of the combined carbon is transformed to free or uncombined carbon.

Carburizing (*Cementation*).—Adding carbon to iron-base alloys by heating the metal below its melting point in contact with carbonaceous material.

NOTE.—The term "carbonizing" used in this sense is undesirable and its use should be discouraged.

Case Hardening.—Carburizing and subsequently hardening by suitable heat treatment, all or part of the surface portions of a piece of iron-base alloy.

Case.—That portion of a carburized iron-base alloy article in which the carbon content has been substantially increased.

Core.—That portion of a carburized iron-base alloy article in which the carbon content has not been substantially increased.

NOTE.—The terms "case" and "core" apply both to carburizing and case hardening.

Cyaniding.—Surface hardening of an iron-base alloy article or portion of it by heating at a suitable temperature in contact with a cyanide salt, followed by quenching.

TENTATIVE SPECIFICATIONS
FOR
FIRE-REFINED COPPER OTHER THAN LAKE[1]

Serial Designation: B 72 – 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1928.

Scope.

1. (*a*) These specifications cover fire-refined copper, other than Lake, and not usually electrolytically refined.

(*b*) Fire-refined copper, other than Lake, is intended for use in rolling into sheets and shapes for mechanical purposes, and for certain grades of wrought-copper alloys, and is not intended for electrical purposes.

CHEMICAL PROPERTIES

Chemical Composition.

2. The copper in all shapes shall conform to the following requirements as to chemical composition:

Copper plus silver, minimum	99.7500	per cent
Arsenic, maximum	0.1000	"
Antimony, maximum	0.0060	"
Bismuth, maximum	0.0002	"
Iron, maximum	0.0050	"
Lead, maximum	0.0075	"
Nickel, maximum	0.1000	"
Oxygen, maximum	0.0750	"
Selenium, maximum	0.0100	"
Sulfur, maximum	0.0075	"
Tellurium, maximum	0.0010	"
Tin, maximum	0.0500	"

Chemical Analysis.

3. The chemical analysis shall be made in accordance with the Standard Methods of Battery Assay of Copper (Serial Designation: B 34) of the American Society for Testing Materials.[2]

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. E. E. Thum, Secretary of Committee B-2 on Non-Ferrous Metals and Alloys, 239 W. Thirty-ninth St., New York City.

[2] 1927 Book of A.S.T.M. Standards, Part I, p. 663.

PHYSICAL DEFECTS

Physical Defects. 4. Wire bars, cakes, slabs and billets shall be substantially free from shrink holes, cold sets, sloppy edges, concave tops, and similar defects in set or casting. This requirement shall not apply to ingots or ingot bars, in which case physical defects are of no consequence.

PERMISSIBLE VARIATIONS IN WEIGHT AND DIMENSION

Permissible Variations. 5. A permissible variation of plus or minus 5 per cent in weight or plus or minus $\frac{1}{4}$ in. in any dimension from the manufacturer's published list or the purchaser's specified size shall be considered good delivery; provided, however, that wire bars may vary in length plus or minus 1 per cent from the listed or specified length, and the cakes may vary plus or minus 3 per cent from the listed or specified size.

MARKING

Marking. 6. All wire bars, cakes, slabs and billets shall be stamped with the manufacturer's brand and furnace charge mark. Ingots and ingot bars shall have a brand stamped or cast in, but need have no furnace charge mark.

LOTS

Lots. 7. The manufacturer shall arrange the car loads or lots so that, when possible, each shall contain shapes from but one furnace charge in order to facilitate testing by the purchaser.

CLAIMS

Claims. 8. Claims, to be considered, shall be made in writing within thirty days of receipt of the material at the purchaser's plant and results of the tests made by the purchaser shall accompany such claims. The manufacturer shall be given one week from the date of receipt of the complaint to investigate his records, and shall then either agree to satisfy the claim or send a representative to the purchaser's plant. No claims shall be considered if the material in question, unused, cannot be shown to the manufacturer's representative.

Claims against quality will be considered as follows:

(*a*) Metal contents by furnace charges, ingot lots, or ingot-bar lots.

(*b*) Physical defects by individual pieces.

(*c*) Variations in weight or dimension by individual pieces.

Inspection. 9. (*a*) The manufacturer's representative shall inspect all pieces where physical defects or variations in weight or dimension are claimed. If agreement is not reached, the question of fact shall be submitted to a mutually agreeable umpire, whose decision shall be final.

Investigation of Claims.

(*b*) In a question of metal contents each party shall select three shapes from the consignment or lot to be investigated. These shapes shall be sampled in the presence of both parties by drilling five holes approximately ½ in. in diameter at points equally spaced between the ends of each piece. Bars, billets, ingots and ingot bars shall be sampled along a center line, while slabs and cakes shall be sampled along a diagonal line projecting between opposite corners. The drillings shall be made from top to bottom and completely through each piece. Scale from set and any surface dirt shall be rejected. No lubricant shall be used and the drilling shall not be forced sufficiently to cause oxidation of the chips. In the case of shapes having a depth greater than 5 in., drillings may be made from both the top and bottom for a depth not less than 2 in. in each direction instead of completely through the shape, but the drilling shall be otherwise conducted as before described.

The resulting sample shall be cut up, thoroughly mixed and separated into three equal portions, each of which shall be placed in a sealed package, one for the manufacturer, one for the purchaser and one for an umpire, if necessary.

Each party shall make an analysis in accordance with Section 3 and if the results do not establish or dismiss the claim to the satisfaction of both parties concerned, the third sample shall be submitted to a mutually agreeable umpire, who shall determine the question of fact and whose determination shall be final.

Settlement of Claims.

10. The expenses of the refiner's representative and of the umpire shall be paid by the loser, or divided in proportion to the concession made in case of compromise.

In the case of rejection being established, the damage shall be limited to payment of freight both ways by the refiner for substitution of an equivalent weight of copper conforming to these specifications.

TENTATIVE SPECIFICATIONS

FOR

SAND CASTINGS OF THE ALLOY: COPPER 80 PER CENT; TIN 10 PER CENT; LEAD 10 PER CENT[1]

Serial Designation: B 74 – 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1928.

Scope. 1. (*a*) These specifications cover alloy castings, the alloy being a composition of copper, tin and lead, known commercially as 80-10-10, deoxidized with phosphorus.

(*b*) The castings are intended for use for bearings and bushings in the cast state. This alloy is frequently used also for castings which are called upon to resist some of the mild acids such as are found in mine waters.

MANUFACTURE

Process. 2. (*a*) The alloy may be made by any approved method.

(*b*) The castings shall be of uniform quality.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition. 3. (*a*) The alloy shall conform to the following requirements as to chemical composition:

	DESIRED	MINIMUM	MAXIMUM
Copper, per cent	80	79	81
Tin, per cent	10	9	11
Lead, per cent	10	9	11
Zinc, per cent	none	....	0.25
Iron, per cent	none	none	0.10
Nickel, per cent	....	....	0.50
Phosphorus, per cent	trace	trace	0.25
Aluminum, per cent	none	....	none
Sulfur, per cent	none	....	0.05
Antimony, per cent	none	none	0.25
Total other impurities, per cent	none	....	0.15

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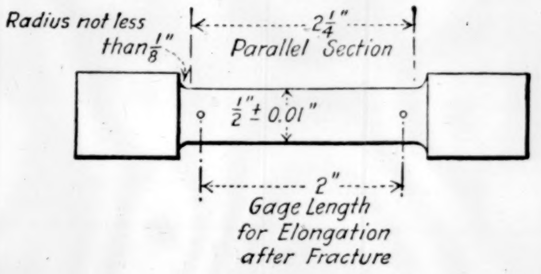
[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. E. E. Thum, Secretary of Committee B-2 on Non-Ferrous Metals and Alloys, 239 W. Thirty-ninth St., New York City.

(*b*) Where "none" is specified it shall be construed to refer to none as determined on a 10-g. sample.

Chemical Analysis.

4. (*a*) An analysis of each melt may be made at the option of the purchaser and at his own expense.

(*b*) The sample for chemical analysis shall be taken from cuttings from the test bars.


Radius not less than $\frac{1}{8}$"
$2\frac{1}{4}$"
Parallel Section
$\frac{1}{2}$" ± 0.01"
2"
Gage Length for Elongation after Fracture

Note:-The Gage Length, Parallel Section, and Fillets shall be as Shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a Way that the Load shall be axial.

FIG. 1.—Tension Test Specimen.

PHYSICAL PROPERTIES AND TESTS

Physical Requirements.

5. (*a*) The alloy shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in.	25 000
Yield point, lb. per sq. in.	12 000
Elongation in 2 in., per cent	6

(*b*) The yield point shall be determined as the stress producing an elongation under load of 0.5 per cent, that is, 0.01 in. in a gage length of 2 in.

(*c*) Castings made from this alloy shall conform to such requirements as to pressure tests as may be mutually agreed upon between the manufacturer and the purchaser and as specified in the contract or purchase order.

Tension Test Specimens.

6. (*a*) The tension test specimen shall be machined from a coupon to the dimensions shown in Fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

(*b*) The coupon attached to the casting shall be in accordance with the dimensions shown in Fig. 2. The fin gate along the side shall not be less than $\frac{5}{16}$ in. in thickness at any point along its length.

Number of Tests.

7. (*a*) Each casting weighing 250 lb. or more shall have, if practicable, at least one test coupon attached. The responsibility of furnishing sufficient test specimens shall rest with the manufacturer.

(*b*) In the case of castings weighing less than 250 lb. each, at least one test coupon shall, if practicable, be attached to one or more castings from each melt or heat or from such groups of melts or heats as the purchaser may specify, but in no case shall a lot consist of more than 1000 lb. of castings.

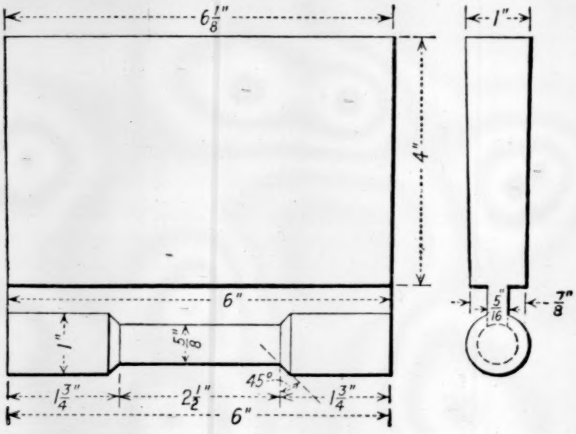


FIG. 2.—Test Specimen Coupon.

(*c*) In the case of castings where, in the opinion of the inspector, it is impracticable to attach a test coupon to the casting, bars shall be cast separately in sand. At least one test bar shall be poured from each melt or heat of metal, or such groups of melts or heats as the purchaser may specify, but in no case shall a lot consist of more than 1000 lb. of castings. The bars shall be cast from the first metal poured from the heat, and the inspector shall witness the pouring of the test mold.

(*d*) If any test specimen shows defective machining or reveals casting defects, it may be discarded and replaced by another specimen selected by the inspector. If additional test coupons are not available, the replacement specimen may be taken from the body of a casting selected by the inspector to represent the lot.

WORKMANSHIP AND FINISH

Finish.

8. (*a*) The castings shall be free from blow holes, porosity, hard spots, shrinkage defects or cracks, or other injurious defects and shall be smooth and well cleaned, before inspection, by sand blasting, tumbling, chipping or other process approved by the inspector.

(*b*) The castings shall not be repaired, plugged, welded, or "burned in" unless permission from the inspector has been previously secured. This permission will be given only when the defects are such that after the approved repair the usefulness and strength of the casting has not been impaired. Each such repair shall be encircled by a ring of white paint at the time of shipment.

(*c*) All castings shall be true to pattern, free from swells, etc. Wall thicknesses shall be uniform throughout the lot of castings and all cores shall be accurately set.

(*d*) Where thick and thin sections join, the manufacturer shall be permitted to add (where not previously provided) fillets of proper size to avoid cracking upon cooling, subject to the approval of the inspector.

MARKING

Marking. 9. The castings shall be marked with pattern or mark number and, when practicable, with the melt or lot number, at a position on the castings where they will not be machined off in manufacture to finished dimensions.

INSPECTION AND REJECTION

Inspection. 10. (*a*) Inspection may be made at the manufacturer's works or at the point of delivery. Inspection is optional with the purchaser.

(*b*) If the purchaser elects to have the inspection made at the manufacturer's works, the inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 11. Castings which show injurious defects revealed by machining operations subsequent to acceptance may be rejected, and if rejected, shall be replaced by the manufacturer without charge to the purchaser. The full weight of the original material rejected shall be returned to the manufacturer.

TENTATIVE SPECIFICATIONS
FOR
BRASS INGOT METAL, GRADED AND UNGRADED, FOR SAND CASTINGS[1]

Serial Designation: B 30 - 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED AS TENTATIVE, 1919; ADOPTED IN AMENDED FORM, 1922;
REISSUED AS TENTATIVE, 1928.

Scope. 1. These specifications cover brass ingot metal for sand castings, known commercially as red and yellow brass ingot, made wholly or partly from scrap materials. Eight typical alloys are specified and are designated Grades Nos. 1 to 8, in accordance with their decreasing copper content as specified in Section 3. These specifications also cover brass ingot metal which has no grade limit, designated as ungraded material, such as a specific lot of ingots having a stated composition suitable for the buyers' needs.

MANUFACTURE

Uniform Quality. 2. The manufacturer shall use care to have each lot of ingot metal as uniform in quality as possible.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition. 3. Individual ingots of any lot shall not show an extreme variation between the high and low copper percentages of more than 2.5 per cent and between the high and low percentages of the other main constituents, except zinc, of more than 1.5 per cent. The graded alloys shall conform to the following requirements as to chemical composition, within the limits specified in Section 4:

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. E. E. Thum, Secretary of Committee B-2 on Non-Ferrous Metals and Alloys, 239 W. Thirty-ninth St., New York City.

These tentative specifications are in effect a revision of the former Standard Specifications for Brass Ingot Metal, Graded and Ungraded, for Sand Castings (Serial Designation: B 30 - 22) which were discontinued in 1928.

Alloy, Grade No.	Copper, per cent	Tin, per cent	Lead, per cent	Zinc, per cent	Impurities, maximum, per cent						Total Other Impurities, per cent
					Iron	Nickel	Antimony	Aluminum	Sulfur	Phosphorus	
1	88	6.5	1.5	4.0	0.15	0.50	0.25	none	0.05	0.05	0.15
2	85	5.0	5.0	5.0	0.25	0.75	0.25	none	0.05	0.05	0.15
3	83	4.0	6.0	7.0	0.25	0.75	0.25	none	0.05	0.05	0.15
4	77	3.0	10.0	10.0	0.25	0.75	0.35	none	0.05	0.05	0.15
5	76	2.0	6.0	16.0	0.25	0.25	0.25	none	0.05	0.05	0.15
6	remainder	2.0	4.0	22.0	0.30	0.25	0.20	none	0.05	0.02	0.15
7	remainder	1.0	2.5	33.0	0.30	0.25	0.20	none	0.05	0.02	0.15
8	63.5	0.0	2.5	34.0	0.75	0.25	0.15	0.3	0.05	0.03	0.15

Permissible Variations.

4. The following permissible variations in the percentages of the desired elements specified in Section 3 will be allowed, but shall not apply to the maximum percentages of impurities specified:

PERCENTAGE OF ELEMENT SPECIFIED	PERMISSIBLE VARIATIONS OVER AND UNDER THE SPECIFIED VALUE, UNITS OF PER CENT
Not over 5 per cent	0.50
Over 5 to 15 per cent, inclusive	0.75
Over 15 per cent	1.00

Samples for Chemical Analysis.

5. (*a*) Ten ingots shall be selected by the inspector to represent 40,000 lb. and five ingots for less than carload lots.

(*b*) The samples for chemical analysis may be taken either by sawing, drilling or milling the ingots and shall represent the average cross-section.

(*c*) The saw, drill, cutter or other tool used shall be thoroughly cleaned. No lubricant shall be used in the operation, and the sawings or metal chips shall be carefully treated with a magnet to remove any particles of steel introduced in taking the sample.

Methods of Chemical Analysis.

6. The chemical analysis shall be made in accordance with the Standard Methods of Chemical Analysis of Brass Ingots and Sand Castings (Serial Designation: B 45) of the American Society for Testing Materials.[1]

MARKING

Marking.

7. The designating mark of the manufacturer, the proper lot number, and the numerical designation of the grade supplied shall be marked on each ingot for identification.

INSPECTION AND REJECTION

Inspection.

8. (*a*) Inspection may be made at the manufacturer's works where the ingots are made, or at the point at which they are received, at the option of the purchaser.

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[1] 1927 Book of A.S.T.M. Standards, Part I, p. 724.

(*b*) If the purchaser elects to have inspection made at the manufacturer's works, the inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

9. If the test ingots selected to represent a lot fail to conform to the requirements specified in Sections 3 and 4, all ingots in such lot will be rejected.

CLAIMS

Claims.

10. Claims, to be considered, shall be made in writing within 30 days of receipt of material at the purchaser's plant, and the results of tests made by the purchaser shall be given. The manufacturer shall, within one week of receipt of such claim, either agree to satisfy the claim or send a representative to the purchaser's plant to re-sample the shipment, as specified in Section 5. Samples so taken shall be sealed and submitted to a mutually agreeable umpire, whose determination shall be final.

Settlement of Claims.

11. The expense of umpire analysis shall be paid by the loser or divided in proportion to the concession made in case of a compromise. In case of rejection being established, the damages shall be limited to the payment of freight both ways by the manufacturer for the substitution of an equivalent weight of ingot metal meeting these specifications.

APPENDIX

The data in the following tables do not constitute a part of these specifications. They are given merely to indicate to the purchaser the physical properties of the various alloys specified which can be expected of carefully manufactured alloys of the formulas indicated, and to constitute a guide to the purchaser in selecting the grade best suited for meeting the service condition for which the ingot metal is to be used.

Alloy Grade No.	Desired Composition, per cent				Tensile Strength, lb. per sq. in.[a]	Elongation in 2 in., per cent	Reduction of Area, per cent	Brinell Hardness (500 kg. for 30 sec.)	Shrinkage, in. per ft.	Weight, lb. per cu. ft.
	Copper	Tin	Lead	Zinc						
1	88	6.5	1.5	4.0	30 000 - 36 000	20 - 25	25 - 30	......	0.125	540
2	85	5.0	5.0	5.0	27 000 - 33 000	16 - 20	15 - 20	50 - 60	0.140	535
3	83	4.0	6.0	7.0	25 000 - 30 000	15 - 20	20 - 26	55 - 60	0.125	538
4	77	3.0	10.0	10.0	23 000 - 28 000	10 - 15	10 - 15	50 - 55	0.125	540
5	76	2.0	6.0	16.0	20 000 - 25 000	15 - 20	10 - 20	43 - 48	0.125	538
6	remainder	2.0	4.0	22.0	20 000 - 25 000	15 - 20	10 - 20	40 - 50	0.125	535
7	remainder	1.0	2.5	33.0	20 000 - 25 000	20 - 25	15 - 25	40 - 50	0.125	533
8	63.5	0.0	2.5	34.0	20 000 - 25 000	20 - 30	20 - 30	40 - 50	0.125	530

[a] The tension tests were made on "sand cast-to-size" test specimens.

Grade No.	Examples of Use	Foundry Manipulation	Characteristics
1	High grade steam metal.[1]	Easily handled	Machines well
2	High grade red brass for general service[2]	Easily handled	Machines more readily than No. 1
3	Medium grade red brass for general service	Easily handled	Machines more readily than No. 1
4	Valve fittings for low pressure	Not difficult	Machines very easily
5	Reddish yellow alloy for air, gas and water fittings	Not difficult	Machines easily
6	Yellowish red alloy for plumbers' fittings	Not difficult	Machines easily
7	Yellow brass for general service	Not difficult	Machines easily
8	General purpose yellow brass for castings not subjected to internal pressures[2]	Not difficult	Machines easily

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[1] Grade No. 1 conforms to the Standard Specifications for Steam or Valve Bronze Sand Castings (Serial Designation: B 61) of the American Society for Testing Materials, see the 1928 Supplement to Book of A.S.T.M. Standards, p. 50.

[2] Grade No. 2 conforms to the Standard Specifications for Composition Brass or Ounce Metal Sand Castings (Serial Designation: B 62) of the American Society for Testing Materials, see the 1928 Supplement to Book of A.S.T.M. Standards, p. 54.

[3] Grade No. 8 conforms to the Standard Specifications for Yellow Brass Sand Castings for General Purposes (Serial Designation: B 65) of the American Society for Testing Materials, see the 1928 Supplement to Book of A.S.T.M. Standards, p. 58.

TENTATIVE SPECIFICATIONS

FOR

SILVER SOLDERS[1]

Serial Designation: B 73 – 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1928.

Scope. 1. (*a*) These specifications cover eight grades of silver-copper-zinc alloys in wire, strip, sheet or granular form, used for brazing purposes and commercially known as silver solders.

(*b*) The eight grades of silver solders covered by these specifications shall be designated as Grades Nos. 1 to 8 in accordance with their chemical composition as specified in Section 6.

(*c*) The choice of the grade of solder for any specified purpose depends on the material in connection with which it is to be used. Recommendations regarding applications and data regarding colors and melting ranges are given in the Appendix to these specifications.

MANUFACTURE

Process. 2. The alloys shall be made from virgin metals or such clean scrap as may result from the manufacture of articles of the same or similar composition.

3. Strip or sheet solder shall be cold rolled to size and, unless otherwise specified, shall be furnished in the hard condition.

4. Wire shall be cold drawn to size, and unless otherwise specified, shall be annealed after cold drawing and pickled bright.

5. Granular solder shall be produced by filing, grinding or other process of granulation. The material shall be supplied in sizes specified in accordance with the requirements for the size of sieve opening of the Standard Specifications for Sieves for Testing Purposes (Serial Designation : E 11) of the American Society for Testing Materials.[2] The material shall contain not more than 10 per cent over the specified size.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. E. E. Thum, Secretary of Committee B-2 on Non-Ferrous Metals and Alloys, 239 W. Thirty-ninth St., New York City.

[2] 1927 Book of A.S.T.M. Standards, Part I, p. 789.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

6. The alloys shall conform to the following requirements as to chemical composition, within the permissible variations specified in Section 7:

Grade No.	Silver, per cent	Copper, per cent	Zinc, per cent	Cadmium, per cent	Impurities, Max., per cent,
1	10	52	38	[a]	0.15
2	20	45	35	[a]	0.15
3	20	45	30	5	0.15
4	45	30	25	nil	0.15
5	50	34	16	nil	0.15
6	65	20	15	nil	0.15
7	70	20	10	nil	0.15
8	80	16	4	nil	0.15

[a] The addition not to exceed 0.50 per cent of cadmium to assist in fabricating Grades Nos. 1 and 2 shall not be considered as a harmful impurity.

Permissible Variations.

7. The permissible variation from the percentages, specified in Section 6, of silver, copper and zinc, for all grades shall be plus or minus 1 per cent in the case of silver and copper and 2 per cent in the case of zinc. The permissible variation in the percentage of cadmium for Grade No. 3 shall be plus or minus 1 per cent.

Sample for Chemical Analysis.

8. A composite sample of not less than 1 oz. shall be taken from each lot of 50 lb. or fraction thereof of Grades Nos. 1, 2 and 3, and from each lot of 20 lb. or fraction thereof of Grades Nos. 4, 5, 6, 7 and 8. Samples of granulated solder shall consist of the grains as prepared. Samples from wire, sheet or strip shall be taken by shearing or clipping pieces from the entire cross-section of the same, remelting in a clean container at a temperature slightly above the melting range, mixing thoroughly, and pouring into a cold mold of convenient size for milling or drilling. The sample so prepared shall be milled or drilled in such a manner as to represent the entire cross-section. All samples shall be clean and free from dirt, oil, oxide or other foreign material.

9. In the case of dissatisfaction, the solder shall be sampled in the presence of representatives of both the manufacturer and the purchaser. The thoroughly mixed sample shall be divided into three equal parts, each of which shall be placed in a sealed package, one for the manufacturer, one for the purchaser, and one for an umpire, if necessary.

PACKING AND MARKING

Packing.

10. The silver solder shall be packed in such a manner as to prevent injury during shipment.

Marking. 11. Each package shall be legibly marked with the grade and size, the weight of the material, brand or trade mark of the manufacturer, and the contract or purchase order number.

WORKMANSHIP AND FINISH

Finish. 12. All wire, sheet and strip shall be smooth and bright, and free from slivers, splitting, or other injurious or objectionable defects.

13. Granular solder shall be free from oxide, dirt, or any foreign material which will impair its working qualities.

REJECTION

Rejection. 14. Solder which fails to conform to these specifications will be rejected and the manufacturer shall be notified.

APPENDIX

The approximate melting points, flow points and colors of the grades are as follows:

Grade No.	Melting Point, deg. Fahr.	Melting Point, deg. Cent.	Flow Point, deg. Fahr.	Flow Point, deg. Cent.	Color
1	1510	820	1600	870	yellow
2	1430	775	1500	815	yellow
3	1430	775	1500	815	yellow
4	1250	675	1370	745	nearly white
5	1280	695	1425	775	nearly white
6	1280	695	1325	720	white
7	1335	725	1390	755	white
8	1360	740	1460	795	white

Solders of Grades Nos. 1, 2 and 3 are suitable for brazing purposes which require a solder that flows more readily than the ordinary copper-zinc brazing solders. Grades Nos. 4 and 5 flow freely at a still lower temperature and are recommended for use where strong joints are required and in such cases where heating to a sufficiently high temperature to flow Grades Nos. 1, 2 or 3 would be injurious to the article being soldered. Grades Nos. 6, 7 and 8 are higher-grade silver solders and are recommended for special cases where a high degree of malleability and ductility is required.

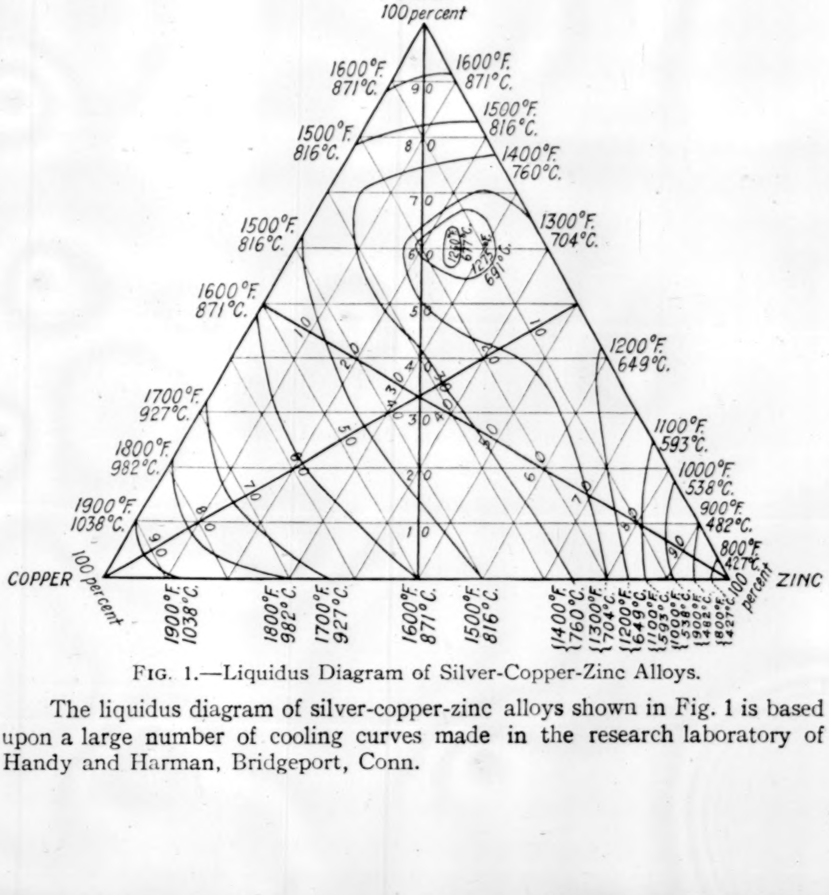

FIG. 1.—Liquidus Diagram of Silver-Copper-Zinc Alloys.

The liquidus diagram of silver-copper-zinc alloys shown in Fig. 1 is based upon a large number of cooling curves made in the research laboratory of Handy and Harman, Bridgeport, Conn.

TENTATIVE SPECIFICATIONS
FOR
SEAMLESS COPPER TUBES[1]

Serial Designation: B 75 – 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1928.

Scope. 1. These specifications cover seamless copper tubes suitable for general engineering uses.

MANUFACTURE

Process. 2. The tubes shall be cold drawn to size.

Temper. 3. (*a*) Unless otherwise specified, the tubes shall be furnished hard drawn.

(*b*) When tubes are ordered "hard," test specimens shall be annealed before testing.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition. 4. The copper shall have a purity of at least 99.90 per cent as determined by electrolytic assay, silver being counted as copper.

Sampling. 5. The sample for chemical analysis shall consist of drillings, millings, or clippings taken from the tubes selected for purpose of tests, as specified in Section 11, equal quantities being taken from each tube and thoroughly mixed. Samples so prepared shall be divided into three equal parts, each of which shall be placed in a sealed package, one for the manufacturer, one for the purchaser, and one for an umpire, if necessary.

PHYSICAL PROPERTIES AND TESTS

Hammering Test. 6. The tubes selected for test shall be capable of standing the following test without showing cracks or flaws: Pieces 4 in. in length cut from the ends of the test tubes shall be hammered flat so that a gage set at three times the thickness of the metal shall pass over the tube freely throughout the flattened part.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. E. E. Thum, Secretary of Committee B-2 on Non-Ferrous Metals and Alloys, 239 W. Thirty-ninth St., New York City.

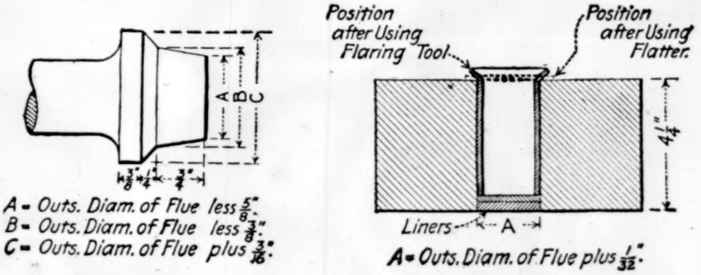
Opening Test.

7. Pieces 3 in. in length cut from each tube selected for test shall, when split, stand opening out flat without showing cracks or flaws.

Bend Test.

8. (*a*) A strip not over $1\frac{1}{2}$ in. in width shall be taken from each test tube which, after annealing, shall stand being bent flat on itself without showing signs of fracture on the outside bent surface, and the ends of the bend test specimen shall stand hammering down hot or cold to a knife-edge without showing signs of cracks.

(*b*) When tubes 2 in. in diameter or under are ordered fully annealed, full sections of the tubes shall stand being bent 180 deg. around a diameter $1\frac{1}{2}$ times the inside diameter of the tube without cracking on the outside bent surface.


A
B
C
3/8"
1/4"
3/4"
A - Outs. Diam. of Flue less 5/8".
B - Outs. Diam. of Flue less 3/8".
C - Outs. Diam. of Flue plus 3/16".
Position after Using Flaring Tool
Position after Using Flatter.
4 1/4"
Liners
A
A - Outs. Diam. of Flue plus 1/32".

Flaring Tool.

Die Block.

FIG. 1.

Flange Test.

9. (*a*) A piece not more than 4 in. in length shall be cut from each test tube and after annealing shall, when cold, have a flange turned over at right angles to the body of the tube without showing cracks or flaws. The width of this flange, as measured from the outside of the tube, shall be one-fourth of the inside diameter of the tube.

(*b*) In making the flange test, it is recommended that the flaring tool and die block shown in Fig. 1 be used.

Hydrostatic Test.

10. Each tube shall stand, without showing weakness or defects, an internal hydrostatic pressure sufficient to subject the material to a fiber stress of 6000 lb. per sq. in., determined by the following formula for thin hollow cylinders under tension:

$$P = 2\frac{tS}{D}$$

where

P = the hydrostatic pressure in pounds per square inch;
t = the thickness of the wall in inches;
D = the outside diameter of the tube in inches; and
S = the allowable unit stress of the material = 6000 lb. per sq. in.

No tube shall be tested beyond a hydrostatic pressure of 1000 lb. per sq. in., unless so specified.

Number of Tests.

11. A number of tubes equivalent to 0.5 per cent of the shipment shall be selected at random for purpose of tests. One hammering, one opening, one bend, and one flange test shall be made on each tube so selected.

TABLE I.—PERMISSIBLE VARIATIONS FROM THE STANDARD TUBE THICKNESS.

Standard Tube Thickness		Diameter, in.			
Stubbs Gage No.	In.	Up to 2, incl.	Over 2 to 4, incl.	Over 4 to 7, incl.	Over 7 to 10, incl.
Over 2-0	Over 0.380	±5 per cent	±5 per cent	±6 per cent	±6 per cent
Under 2-0 to 2, incl.	0.379 to 0.284, incl.	±0.012 in.	±0.014 in.	±0.016 in.	±0.018 in.
Under 2 to 5, incl.	0.283 to 0.220, incl.	±0.010 in.	±0.012 in.	±0.014 in.	±0.016 in.
Under 5 to 8, incl.	0.219 to 0.165, incl.	±0.008 in.	±0.010 in.	±0.012 in.	±0.014 in.
Under 8 to 11, incl.	0.164 to 0.120, incl.	±0.006 in.	±0.008 in.	±0.010 in.	±0.012 in.
Under 11 to 14, incl.	0.119 to 0.083, incl.	±0.005 in.	±0.007 in.	±0.009 in.	±0.011 in.
Under 14 to 17, incl.	0.082 to 0.058, incl.	±0.004 in.	±0.006 in.	±0.008 in.	±0.010 in.
Under 17 to 20, incl.	0.057 to 0.035, incl.	±0.003 in.	±0.005 in.	±0.007 in.	....
Under 20 to 23, incl.	0.034 to 0.025, incl.	±0.0025 in.	±0.004 in.	....	....
Under 23	Under 0.025	±0.0025 in.	....	....	....

DIMENSIONS AND PERMISSIBLE VARIATIONS

Standard Weight.

12. The standard weight of any tube shall be based upon the assumption that one cubic inch of the material weighs 0.323 lb.

Permissible Variations.

13. (*a*) The mean inside or outside diameters of the tubing shall not vary from that specified by more than the following amounts:

MEAN DIAMETER, IN.	PERMISSIBLE VARIATION, IN.
Up to 1, inclusive	±0.0025
Over 1 to 2, inclusive	±0.003
Over 2 to 3, inclusive	±0.004
Over 3 to 4, inclusive	±0.005
Over 4 to 5, inclusive	±0.006
Over 5 to 6, inclusive	±0.007
Over 6 to 8, inclusive	±0.008
Over 8 to 10, inclusive	±0.010

(*b*) No combination of variations on the same tube shall make the thickness of the wall vary from the nominal thickness by more than the amount specified in Table I.

WORKMANSHIP AND FINISH

Workmanship. 14. The tubes shall be free from cracks, seams, slivers, scale and other surface defects.

Finish. 15. All tubes shall be acid cleaned after the final annealing.

INSPECTION AND REJECTION

Rejection. 16. (*a*) When the tubes are finished, and ready for shipment, the inspector shall make the tests to govern the acceptance of the tubes. If any specimen fails to meet the requirements of Sections 6 to 11, inclusive, two additional specimens may be taken, each of which shall conform to the requirements specified.

Inspection. 17. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the tube is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

TENTATIVE METHODS OF CHEMICAL ANALYSIS OF ALUMINUM AND LIGHT ALUMINUM ALLOYS.[1]

Serial Designation: B 40 - 28 T.

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

Issued, 1921; Revised, 1923, 1925, 1926, 1927, 1928.

The methods of analysis listed under "Analysis of Aluminum" contemplate the analysis of aluminum containing more than 98 per cent aluminum and containing only silicon, titanium, iron, copper, carbon and traces of manganese as impurities.

Unless it is positively known that such elements as tin, antimony, zinc, lead, nickel, magnesium, sodium, nitrogen or oxygen (as aluminum oxide) are absent, the methods listed under the "Analysis of Light Aluminum Alloys" should be employed.

ANALYSIS OF ALUMINUM.

(Not less than 98 per cent Aluminum.)

DETERMINATION OF SILICON AND TITANIUM.

DETERMINATION OF TOTAL SILICON.

Solutions Required.

"*Acid Mixture.*"—1200 cc. of H_2SO_4 (25-per-cent by volume), 600 cc. HCl (sp. gr. 1.20) and 200 cc. HNO_3 (sp. gr. 1.42).

25-per-cent Sulfuric Acid.—Pour 250 cc. of H_2SO_4 (sp. gr. 1.84) into distilled water, and dilute to 1000 cc.

Method.

Dissolve 1 g. of the well-mixed sample in 35 cc. of the acid mixture in a covered flat-bottomed porcelain dish or casserole. When the drillings are completely dissolved, boil the solution to complete expulsion of HNO_3 and HCl and heat until copious fumes of H_2SO_4 have been given off for five minutes. Cool and take up the residue with 10 cc. of 25-per-cent H_2SO_4 and 100 cc. of water. Warm to complete solution of the sulfates and filter on an ashless filter paper. Wash the residue with hot water until free from sulfates and ignite in a platinum crucible. Fuse the residue with 8 to 10 times its weight of Na_2CO_3 and treat the fused mass in a casserole or beaker with 20 cc. of H_2SO_4 (1:3), washing out the crucible. Evaporate the solution until it fumes strongly to separate the SiO_2. Cool, dilute to about 100 cc., boil till the salts are dissolved, filter, wash well, ignite in a platinum crucible and weigh. Treat the ash with HF and a few drops of H_2SO_4 (1:3), carefully evaporate till dry, ignite and again weigh.

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[1] Criticisms of these Tentative Methods are solicited and should be directed to Mr. E. E. Thum, Secretary of Committee B-2 on Non-Ferrous Metals and Alloys, 239 W. Thirty-ninth St., New York City.

From the difference between the two weights deduct a blank obtained from the reagents and filter. The rest of the loss in weight represents SiO_2 corresponding to the Si in the metal.

$$SiO_2 \times 0.4672 = Si.$$

NOTES.

Blanks should be carried along with all reagents and the proper corrections made.

In routine analysis, fusion of the first H_2SO_4 residue with sodium carbonate and subsequent treatment to the point of treating the ash with HF may be omitted. The first residue may be weighed and treated with HF, etc., as directed for the second H_2SO_4 residue. This, however, should not be done if the material contains much graphitic silicon or if the residue after ignition is dark colored.

Since there may be a slight loss of silicon in the filtrates from the silica filtrations, this amount should be recovered by repeated evaporations of the filtrates, for accurate work.

DETERMINATION OF TITANIUM.

APPARATUS AND SOLUTIONS REQUIRED.

Nessler tubes or some form of colorimeter.

Hydrogen Peroxide U. S. P.—This reagent must be free from HF.

Standard Titanium Solution.—This solution is best prepared and standardized as follows:[1]

"Potassium titanium fluoride, K_2TiF_6, best serves as the starting point for the preparation of the standard solution. A quantity of this is recrystallized from boiling water one or more times, dried, and preserved in a glass-stoppered bottle. Enough of it to make 0.5 to 1 liter of the standard sulfate solution is put into a platinum dish and evaporated several times with strong sulfuric acid without bringing to dryness, till the fluorine is completely expelled. The residue is then taken up with water containing enough sulfuric acid to make at least 5 per cent of the latter when fully diluted. Two 50 to 100-cc. portions of the prepared solution are then further diluted, boiled, and precipitated with ammonia. The precipitates are collected on paper, washed with hot water till free from alkali, ignited moist in the filter, blasted, and weighed. Duplicates should agree almost exactly. From the weights found, the strength of the standard is calculated and the result affixed to the bottle containing it. The stopper of the bottle should be coated with vaseline and the needed quantities of solution should be withdrawn by a pipette, never poured. In a solution so prepared there is not enough alkali sulfate to weaken the color when peroxidized."

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[1] W. F. Hillebrand, "The Analysis of Silicate and Carbonate Rocks," *Bulletin No. 700*, U. S. Geological Survey, p. 157.

METHOD.

See "Determination of Total Silicon."

Fuse the non-volatile residue remaining after the silicon determination in a small amount of $K_2S_2O_7$, take up in a little 5-per-cent H_2SO_4 and add to the filtrates and washings from the silicon determination. Evaporate the solution to approximately 100 cc., and treat with 5 cc. H_2SO_4 (sp. gr. 1.84) and 3 g. of iron-free zinc. Heat until the zinc is nearly dissolved and the reduction of copper is complete. Decant the solution into another beaker, wash the zinc and copper with hot water and continue the evaporation of the solution to approximately 75 cc. Cool and transfer to a 100-cc. Nessler's comparison tube, add 5 cc. of 3-per-cent H_2O_2 and dilute to the 100-cc. mark. In another tube, place 88 cc. H_2O, 5 cc. of H_2SO_4 (sp. gr. 1.84) and cool. Add 5 cc. of 3-per-cent H_2O_2 and then from a burette add the standard titanium solution until the colors match. The volume of the standard solution required multiplied by 100 times its titre represents the percentage of titanium in the sample.

NOTES.

The filtrate and washings from the Silicon Determination should ordinarily be colorless. If light yellow owing to iron, the standard comparison solution should be brought to the same tint with ferric sulfate solution before adding the hydrogen peroxide.

In case the amount of titanium is high the solution may be diluted to a definite volume and aliquot portions taken for the colorimetric test.

DETERMINATION OF IRON

SOLUTIONS REQUIRED

"*Acid Mixture.*"—1200 cc. of H_2SO_4 (25-per-cent by volume). 600 cc. of HCl (sp. gr. 1.20) and 200 cc. of HNO_3 (sp. gr. 1.42).

Tartaric Acid Solution.—Dissolve 20 g. of tartaric acid crystals in 100 cc. of distilled water.

Dilute Ammonium Sulfide Solution.—Add 15 cc. of NH_4OH (sp. gr. 0.90) to 15 cc. of distilled water and saturate with H_2S; then dilute to 200 cc. with distilled water. Use freshly made.

Dilute Sulfuric Acid Solution for Reductor (5-per-cent).—Mix 50 cc. of H_2SO_4 (sp. gr. 1.84) and 1000 cc. of distilled water.

Standard Potassium Permanganate Solution.—Dissolve 1 g. $KMnO_4$ in 1000 cc. of H_2O, and allow to stand for several days in a glass-stoppered bottle in a dark closet. Filter the solution through prepared asbestos and standardize against 0.1000-g. portions of pure sodium oxalate. Each cubic centimeter is equivalent to approximately 0.00177 g. of iron.

METHOD

Dissolve 1 g. of the well-mixed sample in 35 cc. of the acid mixture and proceed as in "Determination of Total Silicon," until the first insoluble residue is ignited. Treat this with a little concentrated HNO_3 and HF to remove the silicon, then evaporate to dryness. Fuse the unvolatilized part with $K_2S_2O_7$, dissolve in a little H_2SO_4 (5-per-cent) and add to the main solution. Saturate this solution with H_2S and filter. To the filtrate add 25 cc. of the tartaric acid solution, and then with constant stirring, add NH_4OH (sp. gr. 0.90), finally drop by drop, until it is in slight excess. Pass in H_2S for a few moments, warm somewhat and allow the solution to stand. Filter and wash the sulfide precipitate thoroughly with a freshly made dilute ammonium sulfide solution, until all tartaric acid is washed out.

Dissolve the sulfide precipitate through the filter paper with warm dilute H_2SO_4 (1:10), washing the paper thoroughly, alternately with hot distilled water and with 5-per-cent H_2SO_4, using in all about 100 cc. Boil until H_2S is expelled and add, while hot, a few drops of concentrated solution of $KMnO_4$ until a distinct pink color persists. Boil again, cool and pass the solution through the reductor. Wash the beaker and reductor with 150 cc. of dilute H_2SO_4 for reductor and then with 100 cc. of distilled water. Titrate with standard $KMnO_4$ solution.

NOTES

Results of titration should be checked with a blank determination made on corresponding amounts of solutions used.

A small quantity of liquid should always be left in the reductor funnel and air should never be allowed to enter the body of the reductor.

For further details of the use of reductor see "The Chemical Analysis of Iron," by A. S. Blair, or "Quantitive Chemical Analysis," by H. P. Talbot.

The effect of tartaric acid is to form complexes with aluminum, vanadium, chromium, titanium, etc., preventing their precipitation as hydroxides.

Where the iron exists in very small quantities, a gravimetric method is preferable. In this case, double precipitation of iron sulfide is necessary to eliminate all aluminum. Dissolve the second sulfide precipitate in warm dilute H_2SO_4 (1:10), boil, and oxidize the iron with H_2O_2. Add 3 to 4 g. of NH_4Cl and then NH_4OH (sp. gr. 0.90) in considerable excess, with stirring. Filter quickly, dry and ignite the precipitate, weighing as ferric oxide. If an accurate determination of iron is desired, it is necessary to correct for the small accumulation of silica by treatment of the ignited precipitate with H_2SO_4 (—) HF.

In adding the few drops of concentrated solution of $KMnO_4$ for oxidation, only a very slight excess is used. There may be precipitated a very slight amount of manganese oxide but this can be disregarded in passing the solution through the reductor.

DETERMINATION OF COPPER BY ELECTROLYTIC METHOD

APPARATUS FOR ELECTROLYSIS

See the "Determination of Copper by the Electrolytic Method" in the Standard Methods of Chemical Analysis of Manganese Bronze (Serial Designation : B 27) of the American Society for Testing Materials.[1]

SOLUTIONS REQUIRED

Sodium Hydroxide Solution.—Dissolve 250 g. of NaOH in distilled water and dilute to 1000 cc.

Nitric Acid (1:1).—Pour 500 cc. of HNO_3 (sp. gr. 1.42) into distilled water and dilute to 1000 cc.

METHOD

Dissolve 10 g. of the sample in a large casserole or beaker with 150 cc. of the NaOH solution. This should be added in small portions as the action is vigorous for a time. After the action slackens, complete solution may be hastened by warming. When no evidence of further reaction can be seen, dilute to about 700 cc. with water at the boiling temperature. Filter through a strong paper and wash.

Dissolve the residue from the paper with 25 cc. of hot HNO_3 (1:1) into a beaker for electrolyzing, and wash the filter thoroughly with hot water. Boil to expel oxides of nitrogen, add 6 to 8 cc. of H_2SO_4 (1:1), dilute to about 150 cc. and electrolyze. Use a weighed sand-blasted cathode and a current of from 3 to 5 amperes at approximately 10 volts. When the solution is colorless and 1 cc. of the solution gives no copper test with H_2S water on a porcelain plate, remove the solution from the electrodes quickly without interrupting the current. Quickly rinse the cathode in distilled water and then dip it in two successive baths of alcohol. Shake off the excess alcohol and ignite the remainder by bringing it to the flame of an alcohol lamp. Keep the cathode moving continually while the alcohol burns. Weigh as metallic copper.

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[1] 1927 Book of A.S.T.M. Standards, Part I, p. 700.

NOTES

The electrolytic method is preferred for the determination of copper no matter what the percentage.

It is not anticipated that the aluminum will contain tin. In case tin has been found it will be preferable to precipitate with hydrogen sulfide. The sulfides are then to be dissolved, digested in HNO_3 (1 : 1), the metastannic acid filtered off and the electrolysis then carried out.

A staining of the anode indicates the presence of lead or manganese.

Copper, when present in small amounts, may also be determined by potassium cyanide titration. See Standard Methods of Chemical Analysis of Alloys of Lead, Tin, Antimony and Copper (Serial Designation: B 18) of the American Society for Testing Materials.[1]

If the electrolytically deposited copper is not bright in appearance, it should be dissolved from the cathode and redeposited from a sulfuric-nitric acid solution, the operation being carried through in the same way as in the first electrolysis.

DETERMINATION OF MANGANESE.

(*a*) *Persulfate Method.* (For samples containing under 1.5 per cent of Manganese.)

SOLUTIONS REQUIRED

"*Acid Mixture.*"—Pour 400 cc. of H_2SO_4 (sp. gr. 1.84) into distilled water, cool and add 400 cc. of HNO_3 (sp. gr. 1.42). Then dilute the mixture with distilled water to a total volume of 2000 cc.

Silver Nitrate.—Dissolve 1.33 g. of $AgNO_3$ in 1000 cc. of distilled water.

Stock Sodium Arsenite Solution.—To 15 g. of arsenious oxide (As_2O_3) in a 300-cc. Erlenmeyer flask, add 45 g. of Na_2CO_3 and 150 cc. of distilled water. Heat the flask and contents on the steam bath until the As_2O_3 is dissolved. Cool the solution, filter and make up to 1000 cc. with distilled water.

Standard Sodium Arsenite Solution.—Mix 200 cc. of the stock sodium arsenite solution with 2500 cc. of distilled water, and standardize against a measured volume of a standard $KMnO_4$ solution that has been reduced and treated as in the method, or against a suitable standard metal or alloy of the U. S. Bureau of Standards.

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[1] 1927 Book of A.S.T.M. Standards, Part I, p. 691.

One cubic centimeter of this solution should be equivalent to approximately 0.00035 g. of manganese.

Ammonium Persulfate.—Dissolve 6 g. of ammonium persulfate in 100 cc. of distilled water. (This solution should be made up as needed as it deteriorates rapidly.)

METHOD

Use 1 g. of the sample if the manganese is not over 0.2 per cent. For a higher manganese content adjust the size of sample so that it will not contain more than 0.002 g. of manganese. Place it in a 250-cc. Erlenmeyer flask with 30 cc. of the Acid Mixture and heat until solution is complete. Boil until oxides of nitrogen are expelled. Dilute to 100 cc. with boiling-hot water, add 20 cc. of $AgNO_3$ solution and 30 cc. of the persulfate solution, then remove to a moderately warm place to stand for a few minutes for complete development of the permanganic acid. Cool to below 25° C. and titrate with the standard sodium arsenite solution to the disappearance of the pink color.

NOTES

Large amounts of permanganic acid are unstable; on that account samples which contain large amounts of manganese should have correspondingly small samples weighed out.

The ammonium persulfate must be tested for its strength. A good grade should contain about 95 per cent of $(NH_4)_2 S_2O_8$; some lots contain no more than 25 per cent of the salt.

If it is desired, larger amounts of the sample can be used and correspondingly greater amounts of $AgNO_3$ and $(NH_4)_2S_2O_8$ (preferably in the form of stronger solutions).

(*b*) *Bismuthate Method.* (For samples containing less than 1.50 per cent manganese.) (Optional.)

SOLUTIONS REQUIRED

"*Acid Mixture.*"—Pour 400 cc. of H_2SO_4 (sp. gr. 1.84) into distilled water, cool and add 400 cc. of HNO_3 (sp. gr. 1.42). Then dilute the mixture with distilled water to a total volume of 2000 cc.

Nitric Acid (1 : 3).—Pour 250 cc. of HNO_3 (sp. gr. 1.42) into distilled water and dilute to 1000 cc.

Dilute Nitric Acid (3-per-cent).—Pour 30 cc. of HNO_3 (sp. gr. 1.42) into distilled water and dilute to 1000 cc.

Standard Permanganate Solution.—Dissolve 1 g. of $KMnO_4$ in 1000 cc. of distilled water. Allow it to stand for at least one week and then filter through purified asbestos. Standardize against 0.1 g. portions of pure sodium oxalate. One cubic centimeter of this solution should be equal to approximately 0.00035 g. of manganese.

Standard Ferrous Ammonium Sulfate Solution.—Dissolve 12.4 g. of ferrous ammonium sulfate crystals in 950 cc. distilled water, and add 50 cc. of H_2SO_4 (sp. gr. 1.84).

METHOD

In a 250-cc. Erlenmeyer flask, dissolve 1 g. of the sample in 30 cc. of acid mixture by warming on a water bath until solution is complete.

When solution is complete heat to expel all oxides of nitrogen and cool. Dilute with 50 cc. of HNO_3 (1:3) and add 0.5 g. sodium bismuthate. Heat for a few minutes until the purple color has disappeared with or without the precipitation of manganese dioxide. Add a little ferrous ammonium sulfate solution until the solution becomes clear and boil until the oxides of nitrogen are expelled. Cool, add an excess of sodium bismuthate and agitate for a few minutes. Add 50 cc. of 3-per-cent HNO_3 and filter through an alundum crucible or an asbestos pad. Wash with 50 cc. of 3-per-cent HNO_3. Add from a pipette or a burette 10 to 50 cc. (depending on the amount of permanganic acid) of ferrous ammonium sulfate solution and titrate with the $KMnO_4$ solution.

In exactly the same manner carry through a blank determination using the same amounts of acid mixture, HNO_3 (1:3), and sodium bismuthate as was done with the regular sample. Finally, add the exact volume of ferrous ammonium sulfate solution employed and titrate with the $KMnO_4$ solution.

The difference between the volumes required in the two titrations represents the manganese in the sample, and the percentage is found by multiplying this volume by 200 times the manganese titre of the permanganate solution.

NOTES

Large amounts (above 0.01 g. of manganese per 100 cc. of solution) of permanganic acid are unstable; the method can be used with satisfaction for alloys containing high percentages of manganese by decreasing the size of the sample.

The filtrate from the bismuthate must be perfectly clear, as the least particle of bismuthate carried into the filtrate will vitiate the results.

The solution must be cold at time of filtration and titration.

Instead of employing the method of reducing permanganic acid by means of standardized ferrous ammonium sulfate solution and titrating the excess of the reagent, it is possible to reduce the permanganic acid by standard sodium-arsenite solution. See "Determination of Manganese by the Persulfate Method."

The sodium bismuthate reagent should be tested for manganese and used only if its absence is shown.

ANALYSIS OF LIGHT ALUMINUM ALLOYS

A. ALLOYS CONTAINING ONE PER CENT OR LESS OF SILICON

DETERMINATION OF TOTAL SILICON

Proceed as described under "Determination of Total Silicon" under Analysis of Aluminum.

NOTES

In case $PbSO_4$ is present (as evidenced by a white crystallin precipitate quickly settling after stirring) the filtered residue must be washed free from the sulfate with hot dilute HCl (1 : 3). The final washing must be made with hot water.

If the alloy contains much tin an insoluble compound is apt to form on redissolving the sulfates after the first fuming for SiO_2. To avoid this, thoroughly wet all the salts with H_2SO_4 (sp. gr. 1.84) or HCl instead of dilute acid, before adding water.

DETERMINATION OF IRON

Proceed as described under "Determination of Iron" under Analysis of Aluminum.

DETERMINATION OF COPPER BY ELECTROLYTIC METHOD

APPARATUS AND SOLUTIONS REQUIRED

See the "Determination of Copper by Electrolytic Method" under Analysis of Aluminum.

METHOD

For copper contents up to 1 per cent proceed as described under "Determination of Copper by Electrolytic Method" under Analysis of Aluminum.

If the copper content is more than 1 per cent, dissolve a 1-g. sample in a medium size beaker with 20 cc. of the NaOH solution, warming after the reaction slackens. When no further action can be seen, dilute to 200 cc. with hot water, filter and wash with hot water.

Dissolve the metallic residue from the paper into an electrolytic beaker with 10 cc. of hot HNO_3 (1:1) followed by thorough washing. Add dilute H_2SO_4 equivalent to 2 cc. of concentrated acid. Dilute to 150 cc. Electrolyze and finish as described under "Determination of Copper by Electrolytic Method" under Analysis of Aluminum.

DETERMINATION OF MANGANESE

Proceed as described under "Determination of Manganese" under Analysis of Aluminum.

NOTE

If the manganese content is over 2 per cent there is danger of precipitation at the peroxidizing stage. In that case a suitable aliquot of a new solution should be taken for developing the permanganate form.

DETERMINATION OF CALCIUM AND MAGNESIUM

SOLUTIONS REQUIRED

Sodium Hydroxide Solution.—Same as in the "Determination of Copper by Electrolytic Method" under Analysis of Aluminum.

Sodium Carbonate Wash.—Dissolve 1 g. of Na_2CO_3 in 100 cc. of distilled water.

Hydrochloric Acid (1:1).—Mix equal volumes of HCl (sp. gr. 1.19) and distilled water.

Ammonium Sulfide Wash.—Take 10 cc. of NH_4OH (sp. gr. 0.90) dilute to 500 cc., add 10 g. of HN_4Cl and saturate with H_2S.

Bromine Water.—Place 20 to 30 cc. of liquid bromine in a 500-cc. bottle, fill with cold distilled water, and shake thoroughly. Be very careful to avoid contact of the bromine with the skin.

Ammonium Oxalate Solution.—Make a saturated solution by adding $(NH_4)_2C_2O_4$ in excess to distilled water.

Sulfuric Acid (25-per-cent).—See the "Determination of Total Silicon" in Analysis of Aluminum.

Standard Potassium Permanganate.—See the "Determination of Iron" in Analysis of Aluminum.

Microcosmic Salt Solution.—Prepare a clear saturated solution as required.

Ammonium Nitrate Wash.—Mix 80 cc. of HNO_3 (1:1) with 100 cc. of NH_4OH and dilute to 1 liter.

METHOD

Dissolve 2 g. of the sample in 35 cc. of the NaOH solution, add about 0.5 g. of Na_2CO_3. When dissolved, dilute to 250 cc. with hot water, filter, and wash five times with hot sodium carbonate wash. Dissolve the residue from the filter with 40 cc. of hot HCl (1:1) and a few drops of HNO_3, receiving it in a beaker, and wash the filter. Neutralize this solution with NH_4OH and add from 2 to 5 cc. in excess. Pass in H_2S for 2 or 3 minutes. Filter, and wash a few times with an ammonium sulfide wash.

Boil the filtrate vigorously to drive off $(NH_4)_2S$. When sulfur precipitates add a little bromine water and continue boiling until clear and the odor and color of bromine are gone. Add a drop or two of methyl red as indicator to the solution, then NH_4OH carefully till the yellow color appears. Boil for a minute, filter and wash. Add a few drops of NH_4OH, 10 cc. of $(NH_4)_2C_2O_4$ solution and heat near boiling for 30 minutes, keeping ammoniacal. If a precipitate forms, filter through a small, close-textured paper, and wash eight times with small portions of hot water, reserving the filtrate for determining magnesium.

Return the filter to the precipitation beaker, add 130 cc. of hot water and 20 cc. of H_2SO_4 (25-per-cent), then titrate with standard $KMnO_4$ solution. Deduct a determined blank.

The $Na_2C_2O_4$ value of the $KMnO_4$ multiplied by 0.2990 equals the calcium value.

The filtrate from the calcium determination, or the unfiltered solution if clear, is made just acid with HCl, and 20 to 30 cc. of microcosmic salt solution added. Cool, and add NH_4OH drop by drop, stirring vigorously until a crystallin precipitate begins to form. Continue the very slow addition of NH_4OH with stirring until the precipitate no longer forms, and then add one-tenth the volume of NH_4OH (sp. gr. 0.90) and let stand for at least 3 hours. Filter, and wash with a cold ammonium nitrate wash solution. Place in a weighed porcelain or vitreosil crucible and ignite at about 1000° C. until completely white. Weigh as $Mg_2P_2O_7$, and deduct a blank.

$$Mg_2P_2O_7 \times 0.2184 = Mg$$

NOTES

If much Mg is present (over 1 per cent) some of it may be carried down with the sulfides. In that case, dissolve the precipitate with 10 cc. of HCl (1:1), neutralize and add 2 cc. in excess of NH_4OH, precipitate, and filter off the sulfides as before then combine the filtrates.

If the alloy contains manganese, the ignited phosphate should be dissolved and tested for manganese by the (*a*) Persulfate Method as described in the "Determination of Manganese" in the Analysis of Aluminum, deduction being made for pyrophosphate corresponding to the manganese found.

DETERMINATION OF ZINC

(*a*) *Zinc Oxide Method.* (For samples containing 1 per cent of zinc or less.)

SOLUTIONS REQUIRED

Hydrochloric Acid (*1:1*).—Mix equal volumes of HCl (sp. gr. 1.19) and distilled water.

Acid Wash Water.—Slowly stir 10 cc. of H_2SO_4 (sp. gr. 1.84) into 1000 cc. of distilled water, and saturate with H_2S.

Formic Acid Mixture.—Treat 200 cc. of formic acid with 30 cc. of NH_4OH (sp. gr. 0.90) and dilute to 1000 cc.

Formic Acid Wash Water.—Mix 25 cc. of formic acid mixture and 1000 cc. of distilled water and saturate with H_2S.

Hydrochloric Acid (*1:10*).—Mix 100 cc. of concentrated HCl and 1000 cc. of distilled water.

METHOD

Dissolve 2 g. of the sample in a covered 400-cc. beaker in 45 cc. of HCl (1 : 1) added cautiously, followed by 1 cc. of HNO_3 (sp. gr. 1.42) toward the end of the reaction. Boil to complete the solution and to expel oxides of nitrogen. Dilute to 200 cc., precipitate with H_2S, filter, and wash with acid wash water. Boil thoroughly to expel H_2S.

Cool somewhat, add 10 g. of citric acid, dilute to 300 cc., neutralize with NH_4OH using methyl red as indicator, then add 25 cc. of the formic acid mixture. Heat nearly to boiling, and pass in a rapid stream of H_2S for 15 minutes. Filter through a close-textured paper set with a little of the liquid to be filtered. Refilter the first part if cloudy. Wash five times with the formic acid wash water. Dissolve the ZnS from the filter into the original beaker with hot HCl (1 : 10), washing thoroughly with hot water. Boil the solution to expel H_2S. Cool, add 1 g. of citric acid and make just alkaline to methyl red with NH_4OH, dilute to 100 cc., heat, and pass in H_2S for 3 minutes. Add 10 cc. of the formic acid mixture and continue the H_2S for 5 minutes more. Filter through a close-textured, ashless paper set with a little of the liquid to be filtered, and wash five times with the formic acid wash water. To avoid creeping of the precipitate do not fill the paper too near to its top, and do not wet the funnel above the paper.

Ignite the paper and precipitate in a weighed porcelain or vitreosil crucible, starting at a dull red heat and finishing at a moderate red. Cool, and weigh as ZnO. Deduct a determined blank.

$$ZnO \times 0.8034 = Zn$$

NOTE

By starting the second sulfide precipitation in the alkaline condition adherence of sulfide to the container is avoided.

(*b*) *Ferrocyanide Method:* (For samples containing over 1 per cent of zinc.)

SOLUTIONS REQUIRED

Ferrous Sulfate Indicator.—Dissolve 0.2 g. of $FeSO_4 . (NH_4)_2SO_4 6H_2O$ in 50 cc. of distilled water. Prepare fresh, as required.

Standard Potassium Ferrocyanide Solution.—Dissolve approximately 22 g. of $K_4Fe(CN)_6 . 3H_2O$ per liter of distilled water. It is necessary for this solution to contain a small amount of ferricyanide for indicator purposes. If the solution can be allowed to stand for several weeks enough ferricyanide will be formed by oxidation. For immediate use add 0.15 g. of $K_3Fe(CN)_6$ per liter. The ferrocyanide known solution is standardized by titrating solutions containing known amounts of pure zinc, in accordance with the directions for titration given in this method.

METHOD

If the zinc content is between 1 and 3 per cent dissolve 2 g. of the sample in 45 cc. of the HCl. (1:1). If over 3 per cent dissolve 1 g. of the sample in 25 cc. of the HCl. Proceed as in (*a*) Zinc Oxide Method until the first ZnS precipitate has been washed. Return this precipitate on its paper to the original beaker and add 20 cc. of HCl (1:1). When the sulfide has dissolved, filter, and wash with hot water. Boil the solution containing the zinc to expel H_2S, cool, and wash down. Add two drops of methyl red solution (0.1-per-cent), then neutralize with NH_4OH. Make the solution just acid again with HCl and add 3 cc. of concentrated HCl in excess. Dilute to 200 cc. and heat almost to boiling for titration.

Add five drops of the ferrous sulfate indicator then titrate with the standard potassium ferrocyanide solution. Shortly after starting, a blue color appears and obscures the methyl red. When the ferrocyanide has acted on all the zinc, the red tint reappears since the red is stronger than the light green which would otherwise show. Toward the end the standard solution should be added slowly, stirring vigorously after each addition. The end point is reached when an additional drop causes no visible change from blue to red.

DETERMINATION OF NICKEL

BY THE

DIMETHYLGLYOXIME METHOD

SOLUTIONS REQUIRED

Sulfuric Acid (1:1).—Slowly stir 500 cc. of H_2SO_4 (sp. gr. 1.84) into distilled water, cool, and dilute to 1000 cc.

Hydrogen Sulfide Wash Water.—Slowly stir 10 cc. of H_2SO_4 (sp. gr. 1.84) into 1000 cc. of distilled water and saturate with H_2S.

Tartaric Acid Solution (20-per-cent).—Dissolve 20 g. of tartaric acid in distilled water, dilute to 100 cc. and filter if necessary.

Dimethylglyoxime Solution (1-per-cent).—Dissolve 10 g. of dimethylglyoxime in 1000 cc. of alcohol (95-per-cent).

METHOD

Dissolve 1 g. of the sample in 25 cc. of H_2SO_4 (1:1) by warming and adding a drop or two of HNO_3 (sp. gr. 1.42) occasionally until solution is complete. After oxides of nitrogen have been expelled by boiling, add 14 cc. of NH_4OH (sp. gr. 0.90) in order to bring down the acidity to approximately 5 cc. of H_2SO_4 (sp. gr. 1.84) per 100 cc. of solution. Treat with H_2S. Filter off the sulfides, wash with hydrogen sulfide wash water and boil the filtrate until H_2S is expelled. Add a few crystals of $(NH_4)_2S_2O_8$ and boil thoroughly to destroy sulfur and oxidize iron. Add 20 cc. of tartaric acid solution and make slightly ammoniacal. If no precipitate appears add HCl (sp. gr. 1.19) to slight acidity. If a precipitate appears, dissolve in HCl, add 10 cc. of tartaric acid and again make ammoniacal, repeating the operation, if necessary, to get a clear solution. To the weakly-acid solution add dimethylglyoxime solution in such an amount that the ratio of the reagent to nickel is at least four to one. Heat the solution to boiling and make slightly ammoniacal. Allow to digest, while cooling, for two hours. Collect on a weighed Gooch crucible and wash thoroughly with hot water. Dry for 45 minutes at from 110 to 120° C. and weigh. The nickel dimethylglyoxime contains 20.32 per cent of nickel.

B. ALLOYS CONTAINING OVER ONE PER CENT OF SILICON

DETERMINATION OF SILICON

SOLUTIONS REQUIRED

See the "Determination of Total Silicon" under the Analysis of Aluminum.

METHOD

If the silicon content is under 10 per cent use a 1-g. sample and if a content of higher percentage is expected use an 0.5-g. sample. Place the sample in a 350-cc. casserole. Keeping covered as much as possible, cautiously add 35 cc. of the acid mixture. When no further action can be seen evaporate to dryness, taking care to prevent spattering. Heat to strong fuming of SO_3. Cool, moisten with 10 cc. of H_2SO_4 (25-per-cent), add 100 cc. of hot water, and boil to dissolve the salts. Stir in some ashless paper pulp, then filter through a close-textured paper. Wash three or four times with hot water. Evaporate the filtrate to fumes, cool, dissolve with water, add paper pulp, filter, and wash as before.

Ignite the residues in a large platinum crucible. After cooling, add from 5 to 8 g. (depending on the amount of residue) of Na_2CO_3. Stir well and cover with a layer of Na_2CO_3. Fuse cautiously till nearly quiet, then finish with a full Meker flame or its equivalent. Run the melt up the sides of the crucible, cool, and place in a casserole with 60 to 80 cc. of H_2SO_4 (25-per-cent). When the melt has dissolved remove the crucible, washing it into the casserole. Evaporate, and finally heat till heavy fumes are given off, then remove from the heat. When still moderately warm add a little cold water followed by 100 cc. of hot water. Heat to complete solution of soluble salts, but avoid too long a treatment as the SiO_2 tends to redissolve. Filter the liquid, preferably after stirring in some paper pulp, and wash thoroughly with hot water.

Evaporate the filtrate and heat to fuming again to separate any silica which may have escaped the first treatment. This is collected in the same manner as the main portion.

Dry the filters with contents, then ignite in a platinum crucible, cool, and weigh. Moisten with a few drops of H_2SO_4 (1:3) and add several cubic centimeters of HF. Evaporate until dry, ignite, cool, and weigh again. The loss in weight represents SiO_2. After correcting for a determined blank multiply by 0.4672 to find the amount of Si in the sample taken.

NOTE

In diluting the solution after the fuming which succeeds the fusion, adding a little cold water to the warm solution throws out the silica in a more granular form which is less soluble and more convenient to filter.

DETERMINATION OF IRON

METHOD

Dissolve 1 g. of the sample in the acid mixture and proceed as under "Determination of Total Silicon" under Analysis of Aluminum till the first insoluble residue is ignited. Treat this with a little concentrated HNO_3 and HF to remove the silicon, then evaporate to dryness. Fuse the unvolatilized part with $K_2S_2O_7$, dissolve, and add to the main solution. From this point continue by the sulfide separation method as described under "Determination of Iron" under Analysis of Aluminum.

DETERMINATION OF COPPER

METHOD

Dissolve 5 g. of the sample in a large casserole or beaker by adding, in small portions, 150 cc. of the acid mixture used for starting the silicon determination. When the aluminum is dissolved, evaporate to dryness and heat until copious fumes of H_2SO_4 are given off, cool, dissolve by heating with 300 cc. of water, filter, and wash a few times.

Ignite the dark residue in a platinum dish, add 10 cc. of HNO_3 (sp. gr. 1.42), 2 cc. of H_2SO_4 (1:1), and then add HF drop by drop until the silicon has dissolved. Evaporate to fumes to remove the HF. Take up with water and add to the main filtrate.

Pass H_2S into this liquid for several minutes, and filter off the precipitated CuS, washing with 1-per-cent H_2SO_4 saturated with H_2S. Ignite the precipitate in a porcelain crucible, cool, dissolve by heating with some HNO_3 (1:1), transfer to a suitable beaker and finish electrolytically as under "Determination of Copper by Electrolytic Method" under the Analysis of Aluminum.

DETERMINATION OF MANGANESE

METHOD

Proceed as under "Determination of Manganese," (*a*) Persulfate Method, under the Analysis of Aluminum, except that a few drops of HF should be added to remove the silicon when dissolving the sample. After the solution is complete boil a short time to remove most of the HF, then proceed as usual.

TENTATIVE METHODS OF CHEMICAL ANALYSIS OF METALLIC MATERIALS FOR ELECTRICAL HEATING[1]

Serial Designation: B 71 – 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

Issued, 1927; Revised, 1928.

DETERMINATION OF NICKEL

Solutions Required

Concentrated Sulfuric Acid (sp. gr. 1.84).

Concentrated Nitric Acid (sp. gr. 1.42).

Concentrated Hydrochloric Acid (sp. gr. 1.19).

Dilute Sulfuric Acid (1:1).—Slowly stir 100 cc. of H_2SO_4 (sp. gr. 1.84) into 100 cc. of water.

Dilute Sulfuric Acid (1:99).—Slowly stir 10 cc. of H_2SO_4 (sp. gr. 1.84) into 990 cc. of water.

Tartaric Acid (20-per-cent).

Ammonium Hydroxide (sp. gr. 0.90).

Dilute Acetic Acid (1:3).—Mix 1 cc. of acetic acid (sp. gr. 1.04) and 3 cc. of water.

Nitro-Hydrochloric Acid.—Mix 10 cc. of concentrated HNO_3 (sp. gr. 1.42), 30 cc. of concentrated HCl (sp. gr. 1.19) and 40 cc. of water.

Ammonium Bisulfite.—Dissolve 1 g. of ammonium bisulfite in 5 cc. of hot water.

Sodium Dimethylglyoxime.—Dissolve 3 g. of dimethylglyoxime in 100 cc. of NaOH (3-per-cent), made fresh each time used.

Method

Dissolve exactly 1 g. of the alloy sample in 20 cc. of nitro-hydrochloric acid in a covered 600-cc. beaker. Add 20 cc. of dilute H_2SO_4

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[1] Criticisms of these Tentative Methods are solicited and should be directed to Mr. F. E. Bash Secretary of Committee B-4 on High-Temperature and Electrical-Resistance Alloys, Technical Department, Electrical Alloy Division, Driver-Harris Co., Morristown, N. J.

(1:1) and evaporate the liquid carefully to fumes of sulfur trioxide. When the beaker and its contents have cooled, add 100 cc. of water and allow the solution to digest at a low heat until all salts have dissolved. Filter the solution on a 9-cm. paper to remove any silica, and wash the paper and residue thoroughly with hot water or, if an insoluble residue is present, wash with dilute H_2SO_4 (1:99). Ignite the precipitate at a low heat, and treat with 2 cc. of HF, and several drops of concentrated H_2SO_4 in a platinum crucible, and evaporate to dryness. Fuse the residue with a little sodium carbonate, dissolve in HCl and add to the main nickel solution.

Transfer the nickel solution to a 250-cc. graduated flask, and dilute to the mark with cold water. Mix and draw off exactly 50 cc. by means of an accurately calibrated pipette, and transfer this aliquot portion to a 600-cc. beaker. This aliquot portion represents 0.2 g. of the original sample. Add 25 cc. of a 20-per-cent solution of tartaric acid (enough to hold all the iron and chromium in solution), make the solution alkaline with NH_4OH, and then make it acid with an excess of 15 cc. of concentrated HCl (sp. gr. 1.19). Add 35 cc. of a *freshly prepared* solution of sodium dimethylglyoxime, and make the solution ammoniacal, and then make it just acid with dilute acetic acid (1:3). Stir the solution vigorously and allow it to stand at a temperature of from 75 to 90° C., with occasional stirring, for one hour. If an alcoholic solution of dimethylglyoxime was used to precipitate the nickel, the contents of the beaker should be digested at a temperature just short of the boiling point until the odor of alcohol can no longer be detected.

Filter the scarlet precipitate of nickel dimethylglyoxime on a tared Gooch crucible. Wash thoroughly with hot water and dry at 110° C. to constant weight. Cool in a desiccator and weigh. The weight of nickel dimethylglyoxime multiplied by 20.32 and again by 5 gives the percentage of nickel in the sample. This method yields results that are correct within ± 0.35 per cent.

If greater accuracy is desired, use a larger aliquot portion with proportionally larger amounts of reagents and filter the nickel dimethylglyoxime precipitate on an 11-cm. paper and wash thoroughly 18 or 20 times with hot water. Return the paper and precipitate to the 600-cc. beaker, treat with 5 cc. of concentrated H_2SO_4 (sp. gr. 1.84) and 25 cc. of concentrated HNO_3 (sp. gr. 1.42) and boil the liquid gently until strong fumes of sulfur trioxide are evolved.

Having allowed the beaker and its contents to cool somewhat, add 10 cc. of concentrated HNO_3 (sp. gr. 1.42) and repeat the evaporation. Rinse the cover and sides of the beaker with a fine jet of water and fume the solution again to insure the expulsion of every trace of the HNO_3. When cool, add approximately 50 cc. of cold water and boil the contents of the beaker for several minutes, which should result in a perfectly clear solution.

Neutralize with NH_4OH and add an excess of 20 cc. NH_4OH (sp. gr. 0.90). Add 1 g. of ammonium bisulfite dissolved in 5 cc. of hot water. Now electrolize the nickel sulfate solution with a current of from 1 to 2 amperes, using a platinum-gauze weighed cathode and a spiral platinum anode. Continue the electrolysis until the solution has become colorless, and then continue for at least 15 minutes longer. Now test the solution by adding 1 or 2 drops of it to a solution of potassium sulfocarbonate. Pink color indicates the presence of nickel. The amount of the solution withdrawn for this test will not affect the results and may be neglected. This test will show whether or not the electrolysis has been completed. Wash the metal deposited on the cathode with water. Remove the cathode and dip it first into a beaker of distilled water and then into absolute alcohol, dry for a few minutes at a temperature of 80 to 100° C., and weigh. The increase in weight of the cathode multiplied by 100 and divided by the weight of the sample taken gives the percentage of nickel in the sample.

DETERMINATION OF CHROMIUM BY THE PERSULFATE METHOD

SOLUTIONS REQUIRED

Silver Nitrate Solution (0.5-per-cent).—Dissolve 5 g. of $AgNO_3$ in 1000 cc. of water.

Ammonium Persulfate (15-per-cent).—Dissolve 15 g. of the salt in 100 cc. of water. (The solution should be kept in a cool place and should not be used if over three days old. A fresh solution is preferable).

Sodium Chloride (10-per-cent).—Dissolve 100 g. of NaCl in 1000 cc. of water.

Nitro-Hydrochloric Acid.—Mix 30 cc. of concentrated HCl (sp. gr. 1.19), 10 cc. of concentrated HNO_3 (sp. gr. 1.42), and 40 cc. of water.

Sulfuric Acid (1:1).—Slowly stir 500 cc. of concentrated H_2SO_4 (sp. gr. 1.84) into 500 cc. of water.

Standardized Ferrous Ammonium Sulfate Solution.—Dissolve 39.25 g. of ferrous ammonium sulfate in distilled water, add 20 cc. of dilute H_2SO_4 (1:1), dilute to 1 liter, mix thoroughly and standardize against 0.1 *N* potassium permanganate, which has in turn been standardized against the U. S. Bureau of Standards Sodium Oxalate. This solution should be standardized just before using, as its value may change from day to day. One cubic centimeter of 0.1 *N*. solution equals 0.001733 g. of chromium.

Standard Potassium Permanganate Solution (0.1 N).—Dissolve approximately 3.18 g. of pure potassium permanganate in 300 cc. of hot distilled water, boil for 10 to 15 minutes, cool to room temperature, and filter on asbestos. Transfer the solution to a glass-stoppered bottle and allow it to stand for two weeks, at the end of which time filter again on asbestos and transfer to a liter flask and dilute to the mark. This solution should be kept in a dark bottle. After a preliminary standardization against the U. S. Bureau of Standards Sodium Oxalate dilute so as to be exactly 0.1 *N*, and verify this strength by a second comparison with sodium oxalate.

METHOD

Treat approximately 0.2000 g. of the sample in a 500-cc. flask with 20 cc. of nitro-hydrochloric acid and 0.5 cc. of HF (48-per-cent), warm at a moderate temperature (about 60° C.) until the reaction is complete. Add 20 cc. of dilute H_2SO_4 (1:1), 50 cc. of water, and evaporate just to fumes of sulfuric acid. If any salts separate out, redissolve by adding 250 cc. of water and digest on a hot plate until an entirely clear solution results. Remove from the plate and add 1 cc. of $AgNO_3$ solution (0.5-per-cent), and sufficient ammonium persulfate (approximately 15 cc. for 10 to 12-per-cent chromium alloys and 25 cc. for 20-per-cent chromium alloy) to thoroughly oxidize the manganese, and boil for 3 minutes. Add 20 cc. of NaCl solution (10-per-cent), heat on a plate until the manganese dioxide has dissolved completely and boil for five minutes. Cool to room temperature, and add from a burette standardized ferrous ammonium sulfate until the solution turns green, and then add 5 cc. in excess. Titrate this excess back with 0.1 *N* potassium permanganate.

Calculate the percentage of chromium from the following formula:

$$\text{Percentage of Chromium} = \frac{[(A \times B) - C] \times 0.001733}{0.2, \text{ or weight of sample}} \times 100$$

where A = volume in cubic centimeters of ferrous ammonium sulfate used;

B = normality factor of ferrous ammonium sulfate, determined daily;

C = volume in cubic centimeters of 0.1 *N* potassium permanganate used.

DETERMINATION OF IRON
BY THE
CUPFERRON METHOD

SOLUTIONS REQUIRED

Dilute Hydrochloric Acid (1: 1).—Mix equal parts of concentrated HCl (sp. gr. 1.19) and water.

Dilute Hydrochloric Acid (1:19).—Mix 5 cc. of concentrated HCl (sp. gr. 1.19) and 95 cc. of water.

Dilute Ammonium Hydroxide (1:19).—Mix 1 cc. of NH_4OH (sp. gr. 0.90) and 19 cc. of water.

Dilute Sulfuric Acid (1:4).—Slowly stir 1 cc. of concentrated H_2SO_4 (sp. gr. 1.84) into 4 cc. of water.

Dilute Sulfuric Acid (1:9).—Slowly stir 1 cc. of concentrated H_2SO_4 (sp. gr. 1.84) into 9 cc. of water.

Stannous Chloride Solution.—Dissolve 50 g. of stannous chloride in 100 cc. of concentrated HCl (sp. gr. 1.19) and dilute to 1000 cc.

Cupferron (6-per-cent).—Freshly prepared filtered cupferron ($C_6H_5(NO)ONH_4$).

METHOD

For alloys containing 10 per cent or more of iron, use a 1-g. sample, and for alloys containing 2 per cent or less of iron use a 5-g. sample. Dissolve the sample in a 400-cc. covered beaker in 25 to 75 cc. of concentrated HCl (sp. gr. 1.19) at a temperature of about 65° C. Add 2 cc. of concentrated HNO_3 (sp. gr. 1.42), and from 20 to 25 cc. of concentrated H_2SO_4 (sp. gr. 1.84), and evaporate the solution until fumes of sulfur trioxide are given off. After having allowed the beaker and its contents to partly cool, add 50 cc. of warm water and boil the solution for several minutes to dissolve all salts. Filter the liquid on an 11-cm. paper containing some paper pulp, and wash the residue and filter thoroughly with warm water. Reserve the filtrate. Ignite any residue in a platinum crucible until the carbon of the filter paper has burned off. After allowing the crucible to cool, add one or two drops of concentrated H_2SO_4 (sp. gr. 1.84) and several cubic centimeters of HF and evaporate the solution to dryness. Any remaining residue is fused with a few grams of sodium carbonate. Dissolve the fusion in dilute HCl (1:1) and boil to expel carbon dioxide. Add a slight excess of dilute NH_4OH (1:19) and boil the solution for several minutes. Filter, and wash well with hot water. Dissolve the precipitate off of the filter in 20 cc. of hot dilute H_2SO_4 (1:4) and add it to the main filtrate which should have a total volume of not more than 150 cc. Cool the solution to about 15° C., treat with a slight excess of cold, freshly prepared solution of cupferron (6-per-cent), which should cause the complete precipitation of the iron while all the nickel and chromium should remain in solution. A brownish-red, partly amorphous, partly crystallin precipitate should separate out.

As soon as a drop of the reagent causes the formation of a transient snow-white crystallin precipitate, all of the iron is down. Add some ashless paper pulp, and filter the contents of the beaker on an 11-cm. paper, wash the precipitate 18 to 20 times with cold dilute H_2SO_4 (1:9) and finally wash 5 or 6 times with cold dilute NH_4OH (1:19). Discard the filtrate. This ammonia wash dissolves out the excess of cupferron, and will also dissolve any vanadium that might be present.

Ignite the cupferron precipitate, first at a low-red heat and finally at 900 to 1000° C. Transfer the iron oxide to a 150-cc. covered beaker and wash the crucible with 20 cc. of hot HCl (1:1). Add 10 cc. of concentrated HCl (sp. gr. 1.19) and digest the solution at a temperature somewhat short of boiling. Add stannous chloride solution from time to time in amounts sufficient to discharge the yellow color of the ferric chloride, and to provide a few drops in excess. Finish the determination by the Reinhardt-Zimmerman method.

DETERMINATION OF MANGANESE

SOLUTIONS REQUIRED

Nitro-Hydrochloric Acid.—Mix 10 cc. of concentrated HNO_3 (sp. gr. 1.42), 30 cc. concentrated HCl (sp. gr. 1.19) and 40 cc. of water.

Concentrated Nitric Acid (sp. gr. 1.42).

Dilute Nitric Acid (1:200).—Mix 1 cc. of concentrated HNO_3 (sp. gr. 1.42) and 200 cc. of water.

Dilute Sulfuric Acid (1:3).—Slowly stir 1 cc. of concentrated H_2SO_4 (sp. gr. 1.84) into 3 cc. of water.

Standardized Ferrous Ammonium Sulfate Solution.—See the Determination of Chromium by the Persulfate Method.

NOTE.—One cubic centimeter of exactly 0.1 *N* solution equals 0.002769 g. of manganese.

Standard Potassium Permanganate Solution (0.1 N).—See the Determination of Chromium by the Persulfate Method.

METHOD

Dissolve exactly 2.000 g. of drillings in a 400-cc. beaker with 40 cc. of nitro-hydrochloric acid, and when in solution evaporate to a syrupy consistency and take up with 50 cc. of concentrated HNO_3 (sp. gr. 1.42). Evaporate this again and add 100 cc. of concentrated HNO_3 and boil down to 80 cc. Add slowly, 5.5 g. at a time, about 3 g. of potassium chlorate. Boil for at least 5 minutes after the last addition of potassium chlorate to insure complete oxidation of the chromium. Add 100 cc. of water and filter through a thin asbestos pad with suction, washing the beaker and pad thoroughly with dilute HNO_3 (1:200), leaving no trace of oxidized chromium. Transfer the pad and the precipitate into the original beaker, being sure to wash out all precipitate adhering to the sides of the funnel with cold water.

Now add 100 cc. of distilled water, 50 cc. of dilute H_2SO_4 (1:3), and 5 cc. in excess of enough ferrous ammonium sulfate to dissolve all of the manganese dioxide. (About 20 cc. should be required for the weight of alloy taken). The normality factor of the ferrous ammonium sulfate must be determined just before using. Stir until all the manganese dioxide is dissolved, and titrate the excess of ferrous ammonium sulfate with 0.1 N potassium permanganate. Occluded oxidized chromium is usually the cause for high manganese results.

Calculate the percentage of manganese from the following formula:

$$\text{Percentage of Manganese} = \frac{[(A \times B) - C] \times 0.002769}{2, \text{ or weight of sample}} \times 100$$

where A = volume in cubic centimeters of ferrous ammonium sulfate used;

B = normality factor of ferrous ammonium sulfate, determined daily;

C = volume in cubic centimeters of exactly 0.1 N potassium permanganate used.

DETERMINATION OF CARBON
BY THE
VOLUMETRIC METHOD

This method for the determination of carbon is the method for determining carbon by absorption of the carbon dioxide in barium hydroxide solution. Reference should be made to the Determination of Carbon by the Direct-Combustion Method as described in the Standard Methods of Chemical Analysis of Plain

Carbon Steel (Serial Designation: A 33) of the American Society for Testing Materials.[1]

In a laboratory where accurate results are being obtained by the gravimetric method, or where a large number of samples are to be analyzed, and good weighing methods are in use, the gravimetric method may be used as described in method (*a*) of the Determination of Carbon by the Direct-Combustion Method described in Methods A 33.[2] Where only occasional samples are to be run, it is probable that the volumetric method will give more satisfactory results.

SAMPLE

The sample should weigh at least 4 g. and should be rather finely divided in order that such a large sample may be placed in the combustion boat. Ordinary turnings are satisfactory, except that they are bulky. Usual precautions should be used in obtaining a perfectly clean sample.

APPARATUS

Boats and Lining Material.—Zirkite boats 100 mm. long, 13 mm. wide, and 8 mm. deep (inside dimensions) are most satisfactory, although alundum or porcelain boats may be used. The boats should be ignited in a muffle furnace before using. The bottom of the boat should be lined with a trench of 40-mesh high-grade chrome ore, ignited at 1000° C. and preserved in a glass-stoppered bottle. The sample should be covered with a very thin layer of alundum. Some alundum powder should be sprinkled inside the combustion tube to prevent the boat from sticking.

Flux.—Exactly 2 g. of fine drillings of ingot iron of known carbon content should be sprinkled over the sample before the alundum is placed over the top of the whole charge. The purpose of the ingot iron is not to flux the sample, but is a source of additional heat due to its rapid combustion when the oxygen is turned on. The results must be corrected for the amount of carbon added through the use of ingot iron.

Furnace and Combustion Tube.—The standard electric combustion furnace in common use may be used, but as the temperatures are considerably higher, the life of the heating element will be shorter than usual. A pyrometer should always be used. A fused-silica tube 24 in. in length and 1 in. in diameter gives the best results. The ends of the tubes should be encased in water-cooled jackets, or strips of blotting paper partly immersed in water should be placed over the ends of the tubes. At least 8 in. of the tube next to the

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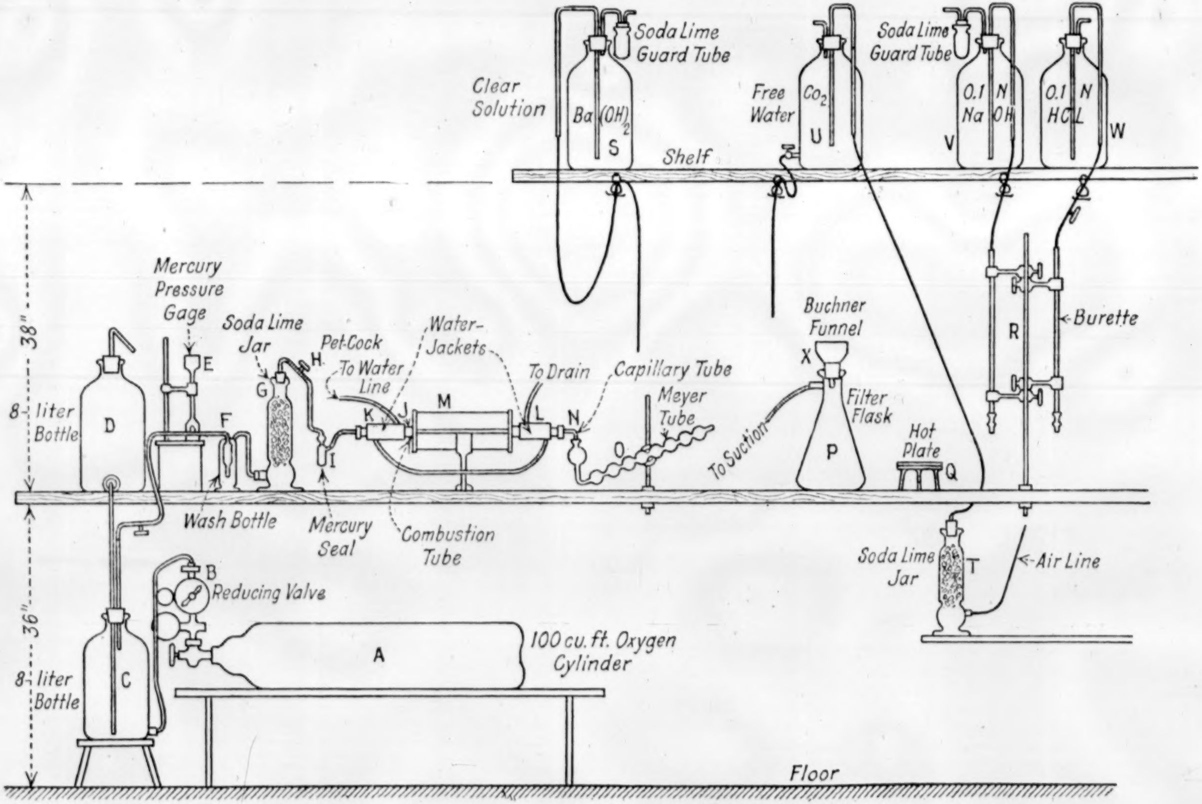
[1] 1927 Book of A.S.T.M. Standards, Part I, p. 276.

[2] *Ibid*, p. 278.


Soda Lime Guard Tube
Clear Solution
Ba(OH)2
S
Shelf
Free Water
Co2
U
Soda Lime Guard Tube
0.1 N NaOH
V
0.1 N HCL
W
38"
Mercury Pressure Gage
E
Soda Lime Jar
G
H
Pet-Cock
To Water Line
Water-Jackets
To Drain
Capillary Tube
Buchner Funnel
X
R
Burette
8-liter Bottle
D
F
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J
M
L
N
Meyer Tube
O
To Suction
Filter Flask
P
Hot Plate
Q
Wash Bottle
I
Mercury Seal
Combustion Tube
Soda Lime Jar
T
Air Line
B
Reducing Valve
36"
A
100 cu. ft. Oxygen Cylinder
8-liter Bottle
C
Floor

FIG. 1.—Apparatus for the Determination of Carbon by the Volumetric Method.

absorption apparatus is filled with asbestos fiber which has been saturated with a solution of ferric nitrate and heated overnight at 1000° C. Ferric oxide will serve to oxidize any carbon monoxide formed, and will convert any sulfur dioxide to ferric sulfate. In case a combustion tube 30 in. in length is used, the dead space in the end next to the absorption apparatus should be filled with a glass plunger, which will decrease the amount of gas that has to be flushed out at each determination. The glass plunger may consist of a glass cylinder with the ends closed.

Detailed Description of Apparatus.—Figure 1 illustrates the details of the apparatus. Oxygen from the 100 cu. ft. cylinder *A*, passes through the reducing valve *B*, to the lower 8-liter-capacity bottle *C*, from which it forces distilled water to the upper bottle *D*, which is 2.5 ft. higher than *C*. When the lower bottle is nearly full of oxygen, the valve *B* is closed and the gas, now under reduced pressure, can be supplied to the apparatus at the desired rate by means of the petcock *H*. One of the essential parts of the apparatus is the mercury pressure gage *E*, which has a 6-in. scale with $\frac{1}{8}$-in. subdivisions, for indicating the *pressure*, and, when calibrated, the *rate of flow* of the oxygen.

To calibrate the gage, the Meyer tube *O*, is filled to the usual point and the oxygen is regulated until the mercury stands at the desired mark, say 1$\frac{1}{8}$ in. The volume of oxygen passing through the apparatus per minute is then determined by collecting it over water in a graduated cylinder, the connection being made to the exit end of the Meyer tube by means of a rubber tube. The rate of flow at 1-in. pressure should be about 100 cc. per minute, although, of course, this varies with the resistance offered to the flow of the oxygen by the reagents and materials in the train.

The capillary tube *N*, in the stopper at the exit of the combustion tube *J*, is an essential part of the apparatus. The size of the capillary opening is adjusted by heating in a flame so that when the mercury gage indicates a certain definite pressure (about 1 in.), the rate of flow through the capillary, the Meyer tube, *O*, being filled and connected, closely approximates but does not exceed 100 cc. per minute. If the rate of flow much exceeds 100 cc. per minute some carbon dioxide will be swept through the barium hydroxide without being absorbed, while if it is much less than 100 cc. all of the carbon dioxide will not be flushed out of the combustion tube in the specified time. Removal of any carbon dioxide in the oxygen is effected by passage through NaOH solution (sp. gr. 1.27) contained in the wash bottle *F*, and the 12-mesh soda lime in the jar *G*, although the principal function of the liquid in *F* is to serve as an indicator of the rate of flow of the gas. The mercury seal *I*, prevents any possibility of back flow of the gases in the combustion tube. After passing through the mercury seal the oxygen enters the combustion tube *J*, which is provided with tightly-fitting one-hole rubber stoppers and with water jackets, *K* and *L*, at the ends. The clear solution of barium hydroxide (20 g. per liter) in the bottle *S*, is arranged so that it can be conveniently siphoned into the eight-bulb Meyer tube, *O*. The barium carbonate is filtered on the Buchner funnel *X*, shown fitted to the filter flask *P*, and the precipitate is washed with carbon-dioxide-free distilled water (prepared by bubbling through the water, compressed air previously freed from carbon dioxide by passage through the soda-lime bottle *T*, delivered by gravity from the bottle *U*). The standard 0.1 *N* solutions of NaOH and HCl are delivered by gravity to the burettes, *R*, from the bottles *V* and *W*. The small hot plate *Q*, is used for warming the flask containing the barium carbonate and the measured amount of 0.1 *N* HCl, in order to cause rapid and complete solution of the precipitate.

METHOD

The furnace having been previously heated to approximately 1100° C., all air having been displaced from the apparatus by passage of a stream of pure oxygen, and the Meyer tube having been filled with sufficient barium hydroxide solution (20 g. per liter) to fill seven of the eight bulbs when the oxygen is passing at the maximum rate, the boat is quickly inserted, by means of a stout copper rod, into the hottest part of the furnace and the stopper immediately replaced. Allow the boat and its contents to heat for about 1 minute with no oxygen passing, this will result in some oxygen being absorbed by the iron, and the barium hydroxide being drawn back into the large bulb as a consequence of the partial vacuum resulting therefrom. At the expiration of about one minute, admit oxygen to the tube at a rate of approximately 340 cc. per minute (as indicated by the gage, which should read about 1½ in.). Complete combustion of the ingot iron, and the alloy sample, with vivid incandescence, should result in 1½ to 2 minutes. Preliminary heating followed by the rapid admission of oxygen are absolutely essential to securing complete combustion in the short time allowed. Only in case the oxides are so thoroughly fused as to show no trace of the shape of the original drillings when the boat is removed from the furnace, should the combustion be considered to have been successful. Upon the appearance of the faintest cloudiness in the first bulb of the Meyer tube, decrease the rate of flow immediately to 100 cc. per minute (about 1 in. on the gage), and maintain it so to the end of the operation. If the rate of flow after the first noticeable formation of barium carbonate is much less or much greater than 100 cc. per minute, low carbon results will be obtained, due either to some carbon dioxide not having been swept out of the apparatus in the time specified, or to some having escaped absorption in the barium hydroxide. Passage of oxygen for a total of 5 minutes is sufficient to sweep all carbon dioxide from the combustion tube.

At the conclusion of the above described operations (6 minutes after the boat was inserted into the furnace) remove the boat, and filter the contents of the Meyer tube on two super-imposed, open-grain, 11-cm. filter papers supported on a Buchner funnel fitted to a suction flask. Wash the Meyer tube three times with water free from carbon dioxide (prepared by passing compressed air through soda-lime and then bubbling it through the distilled water), taking care to reach all points of the tube; then give the precipitate and paper four additional washings. Delivery of the water from an overhead bottle rather than from a wash flask avoids danger of contamination from the carbon dioxide of the breath, besides being more convenient and sanitary. Transfer the paper and precipitate to a 500-cc. Erlenmeyer flask and add from a burette enough standard 0.1 *N* HCl solution to dissolve the barium carbonate and add 5 cc. in excess, a portion of the acid being used to rinse the Meyer tube, which is then further rinsed with water. Place the flask containing the precipitate on a hot plate until the carbonate has dissolved; long heating should be avoided as it apparently causes some action on the filter paper involving a slight error in the determination. Introduce 5 or 6 drops of methyl orange into the solution and determine the excess of HCl by titration with a standard 0.1 *N* solution of NaOH, the end point being marked by the color change from red to yellow. One cubic centimeter of standard 0.1 *N* HCl equals 0.000600 g. of carbon.

A blank should be run on the ingot iron, boat, filter paper, etc., and any carbon found should be deducted from that obtained in the analysis. A 2-g. sample of ingot iron should be used, and the determination made by the method as just described.

DETERMINATION OF INSOLUBLE RESIDUE

METHOD

The sample should weigh at least 5 g. and if the alloy is known to be low in insoluble residue a 10-g. sample should be used. Treat the sample with from 200 to 400 cc. of HCl (sp. gr. 1.19) at a temperature of from 60 to 70° C. until the reaction appears to be complete, then add 1 to 2 cc. of HNO_3 (sp. gr. 1.42). Boil the solution for about 2 minutes, dilute with an equal volume of hot water, filter, and wash the filter thoroughly with hot dilute HCl (5:95).

Ignite the residue at a low heat in a platinum crucible, treat with HF and several drops of dilute H_2SO_4 (1:1), and evaporate the solution just to fumes of sulfur trioxide. If any residue remains, add 10 cc. of water to the crucible, filter on a 9-cm. paper and wash the residue with hot water. Ignite any residue remaining on the paper and weigh. The increase in weight multiplied by 100 and divided by the weight of sample taken gives the percentage of insoluble residue.

DETERMINATION OF SILICON

METHOD

Treat a 2-g. factor-weight sample (0.9344 g.) to a 5-g. factor-weight sample (2.3360 g.) in a 300-cc. porcelain casserole with 30 to 50 cc. of HCl (sp. gr. 1.19), the casserole being covered with a watch glass, and warm until the reaction is complete. Add 30 to 50 cc. of dilute H_2SO_4 (1:1), and evaporate just to fumes of sulfur trioxide. Allow the casserole to partly cool, add 200 cc. of warm water and boil briskly for several minutes to dissolve all salts. Filter the silica on an 11-cm. paper containing some ashless paper pulp, wash five or six times with dilute HCl (1:100), and finally with hot water until free from acid.

Ignite the paper and the precipitate in a small platinum crucible, first at a dull-red heat until the carbon of the filter paper has been oxidized, and finally at 1050 to 1100° C. Allow the crucible to cool in a desiccator and weigh. Add 1 or 2 drops of H_2SO_4 (sp. gr. 1.84), several cubic centimeters of HF, and evaporate the solution until all the H_2SO_4 has been expelled. Ignite the crucible again, cool, and weigh. The difference between the first and the second weights, multiplied by 100 and divided by the weight of sample taken, gives the percentage of silicon in the sample. In case the silica precipitate contains any undissolved material, ignite the paper and the precipitate at a dull-red heat until the carbon of the filter paper has been oxidized, transfer to a 30-cc. pure-iron crucible, and fuse with approximately 5 g. of sodium peroxide. When cool, transfer the melt to a 300-cc. porcelain casserole and dissolve in 50 cc. of water. Add 50 cc. of dilute H_2SO_4 (1:1), and evaporate the solution just to fumes of sulfur trioxide. From this point proceed as described above.

DETERMINATION OF SULFUR BY THE EVOLUTION-TITRATION METHOD

This method is based on (1) the evolution of practically all the sulfur in the alloy as hydrogen sulfide when the alloy is dissolved in HCl (sp. gr. 1.19) (see Note); (2) absorption of the evolved gas by means of an ammoniacal solution of cadmium chloride; and (3) determination of the sulfur by titration with a standard solution of potassium iodate (0.0312 *N*).

SOLUTIONS REQUIRED

Potassium Permanganate Solution (2.5-per-cent).—Dissolve 2.5 g. of $KMnO_4$ in 100 cc. of water.

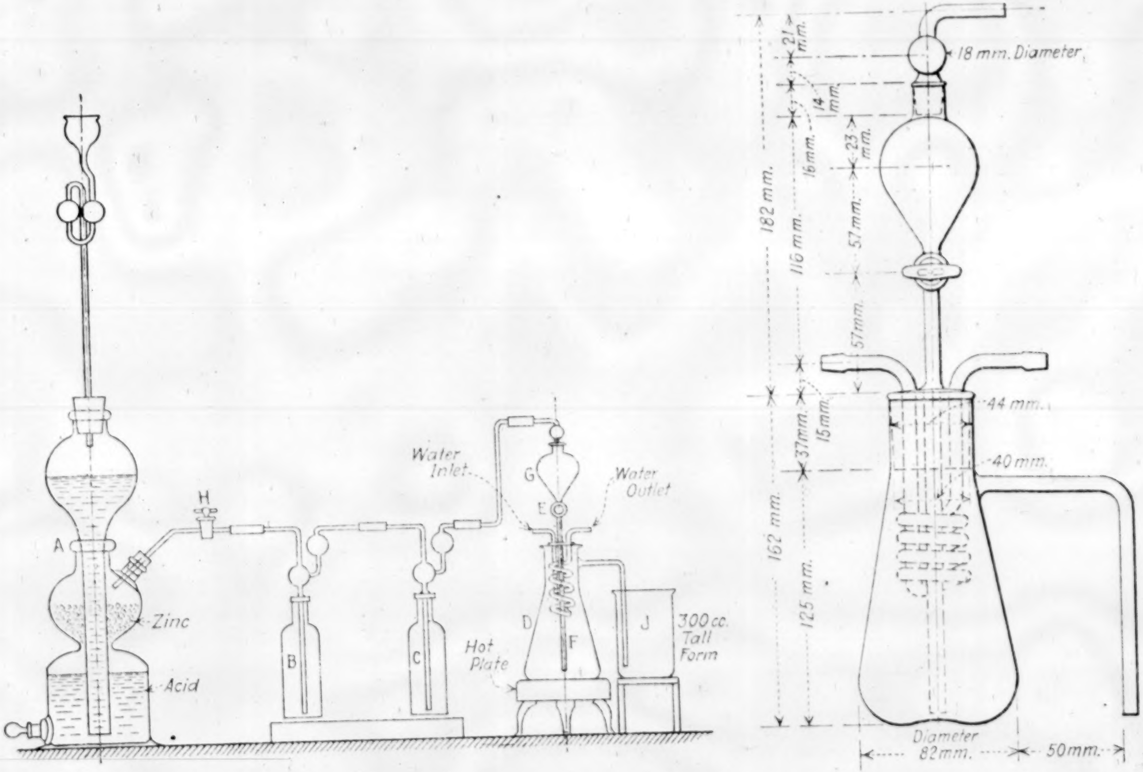
Sodium Hydroxide (30-per-cent).—Dissolve 30 g. of NaOH in 100 cc. of water.

Cadmium Chloride Solution.—Dissolve 10 g. of $CdCl_2 \cdot 2H_2O$ in 400 cc. of water and 600 cc. of NH_4OH (sp. gr. 0.90).

Starch Solution.—Dissolve 1.2 g. of soluble starch in 100 cc. of boiling water, cool to room temperature and add a solution of 0.5 g. of KI dissolved in 10 cc. of cold, freshly distilled water. The starch solution shall not be used if it is over one day old.

Standard Potassium Permanganate (0.03 N).—Dissolve 0.99 g. of pure $KMnO_4$ in 1000 cc. of hot distilled water, boil for 10 minutes, cool to room temperature and filter through asbestos. Standardize against the U. S. Bureau of Standards standard sodium oxalate as follows: In a 200-cc. beaker, dissolve 0.1 g. of sodium oxalate in 75 to 100 cc. of hot water (80 to 90° C.) and add 4 cc. of H_2SO_4 (1:1). Titrate at once with the permanganate solution, stirring the liquid vigorously and continuously. The permanganate must not be added more rapidly than 10 to 15 cc. per minute, and the last 0.5 to 1 cc. must be added dropwise, with particular care to allow each drop to be fully decolorized before the next is introduced. The excess of permanganate used to cause an end-point color must be estimated by matching the color in another beaker containing the same bulk of acid and hot water. The temperature of the solution should not be below 60° C. by the time the end point is reached. Calculate the exact normality of potassium permanganate from the sodium oxalate.

Standard Sodium Thiosulfate (0.03 N).—Dissolve 7.5 g. of $Na_2S_2O_3 \cdot 5H_2O$ in 1000 cc. of freshly boiled, distilled water at room temperature. To 250 cc. of distilled water in a 500-cc. flask add 1 g. of KI and 10 cc. of HCl (1:1). Cool and add 35 cc. of the standard potassium permanganate solution (0.03 *N*) from a burette. Swirl gently and titrate the liberated iodine with the thiosulfate solution to a light straw color. Add several cubic centimeters of the freshly


A
Zinc
Acid
H
B
C
Water Inlet
G
E
Water Outlet
D
F
Hot Plate
J
300 cc. Tall Form
18 mm. Diameter
21 mm.
14 mm.
16 mm.
23 mm.
182 mm.
116 mm.
57 mm.
57 mm.
15 mm.
37 mm.
44 mm.
40 mm.
162 mm.
125 mm.
Diameter 82 mm.
50 mm.

Decomposition Flask, Pulsifer Design.

FIG. 2.—Apparatus for Determination of Sulfur by the Evolution-Titration Method.

prepared starch solution and continue the titration to the disappearance of the blue color. Calculate the normality of the thiosulfate solution from the standard permanganate solution.

Standard Potassium Iodate (0.0312 N).—Dissolve 1.12 g. of pure KIO_3, and 12 g. of KI in 1000 cc. of distilled water. To 250 cc. of cold distilled water in a 500-cc. flask, add 10 cc. of HCl (1:1) and then as the flask is gently swirled, add 35 cc. of the iodate solution from a burette. Titrate the liberated iodine with the standard sodium thiosulfate solution (0.03 *N*) to a light straw color, add several cubic centimeters of the freshly prepared starch solution and continue titration to the disappearance of the blue color. Calculate the normality of the iodate solution and adjust the solution so that 1 cc. is equivalent to 0.0005 g. of sulfur.

APPARATUS

Figure 2 illustrates the details of the apparatus employed. Hydrogen supplied from the Kipp generator, *A*, is freed from any sulfur by passage through a solution of potassium permanganate (2.5-per-cent) contained in a Drechsel bottle, *B*, and sodium hydroxide (30-per-cent) held in the Drechsel bottle, *C*. Hydrogen is admitted through a glass stopcock, *E*, to the decomposition flask, *D*. The decomposition flask (Pulsifer's design) is provided with a ground-glass stopper, *E*, a funnel, *G*, and a cooling coil, *F*, with inlet and outlet tubes. An ammoniacal solution of cadmium chloride or some other suitable absorbent is held in a 300-cc. beaker, *J*. The absorption should not be carried on in direct sunlight.

NOTE.—It is advisable to use an all-glass apparatus because the length of time (30 minutes) required for the solution of the alloy gives opportunity for fumes of hydrochloric acid to attack rubber stoppers and rubber hose connections, which always contain sulfur, and thus cause erroneous results.

METHOD

Transfer to the decomposition flask 5.00 g. of the alloy ribbon which has been cut into very small pieces or of the wire sample which has been flattened by means of a hammer and cut into small pieces. Pass a stream of hydrogen from the Kipp generator through the apparatus to displace the air. Pour 25 cc. of cadmium chloride solution into the beaker, *J*, and add sufficient water to give a depth of 3 in. of the solution. Stop the hydrogen by closing the control stopcock, *H*, on the Kipp generator. Close the stopcock *E*. Remove the ground-glass tube leading into the funnel, *G*, and introduce 100 cc. of HCl (sp. gr. 1.19) (see Note) into the decomposition flask through the funnel. As soon as the acid has been added, replace the ground-glass inlet tube, open the stopcock, *E*, and pass a steady stream of hydrogen through the apparatus during the remainder of the determination. Apply sufficient heat to the decomposition flask to maintain a steady decomposition of the sample. Passage of a stream of cold water through the cooling coil, *F*, of the decomposition flask serves to cool the stopper and to aid in maintaining the strength of the acid in the flask. Thirty minutes of this treatment is ordinarily sufficient to cause complete decomposition. When there is no further action, boil the solution in the decomposition flask for several minutes and continue the stream of hydrogen for 5 minutes longer.

At the end of this time remove the absorption beaker, *J*, close stopcock, *E*, and the control stopcock, *H*, and discontinue heating the decomposition flask. Filter the cadmium chloride solution through an 11-cm. filter paper and wash the precipitate several times with water. Return the paper and precipitate to a 600-cc. beaker, add 300 cc. of cold water and 40 cc. of dilute HCl (1:1) and titrate the liberated hydrogen sulfide with the standard solution of potassium iodate, starch solution being used as an indicator.

Carry a blank through all steps of the process and deduct any sulfur that is found.

If the potassium iodate solution has been adjusted to 0.0312 *N* and 5 g. of the alloy has been dissolved, then the percentage of sulfur is 0.01 times the number of cubic centimeters of the iodate solution used.

NOTE.—There is a question whether concentrated HCl or dilute HCl should be used. This method calls for concentrated HCl. See article by Pulsifer, "A Standard Apparatus for the Determination of Sulfur in Iron and Steel by the Evolution Method" in *Industrial and Engineering Chemistry*, p. 545, 1918.

OPTIONAL METHOD

For an optional method see the Determination of Sulfur by the Evolution-Titration Method (Routine) in the Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial Designation: A 33) of the American Society for Testing Materials.[1] This optional method may be used for Nickel-Chromium and for Nickel-Iron-Chromium Alloys with the following precautions:

1. Due to the length of time (30 minutes) required for solution of the alloy, closer observation is necessary than in the analysis of steel.
2. During the solution of the sample, care must be exercised in order that the absorbing solution is not drawn back into the flask.
3. There is danger of contamination from rubber hose connections and rubber stoppers.
4. The use of a gas flame is a possible source of sulfur contamination and an electric heater is recommended.

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[1] 1927 Book of A.S.T.M. Standards, Part I, p. 293.

TENTATIVE SPECIFICATIONS
FOR
KEENE'S CEMENT[1]

Serial Designation: C 61 - 28 T

This is a Tentative Standard, published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1926; REVISED, 1928.

Various manufacturers offer to the trade several grades of Keene's cement of different finenesses and setting times. These specifications are applicable to the grades manufactured for use in the base and finish coats of plastering. Grades intended for use in Scagliola, castings and other special purposes, should conform to the requirements of these specifications in all respects except those for fineness and time of set, which will vary according to the particular use for which the grade is designed.

Definition. 1. Keene's cement is anhydrous calcined gypsum, the set of which is accelerated by the addition of other materials.

PROPERTIES

Time of Setting. 2. Keene's cement shall not set in less than 2 hours nor more than 4 hours.

Tensile Strength. 3. The cement shall have a tensile strength of not less than 450 lb. per sq. in. (31.5 kg. per sq. cm.).

Fineness. 4. The cement shall all pass a No. 14 sieve,[2] not less than 98 per cent shall pass a No. 40 sieve and not less than 80 per cent shall pass a No. 100 sieve.

Combined Water. 5. The cement shall not show a combined water content of more than 2 per cent.

SAMPLING

Sampling. 6. At least 3 per cent of the packages shall be sampled and shall be so selected as to be representative of the contents of the shipment. Samples shall be taken from both the surface and the center of each package so selected. The material so obtained shall be thoroughly mixed and reduced by quartering to provide not less than a 15-lb. (6.75 kg.) sample for the laboratory.

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[1] **Criticisms of these Tentative Specifications are solicited and should be directed to Mr. H. J.** Schweim, Secretary of Committee C-11 on Gypsum, United States Gypsum Co., 300 W. Adams St., Chicago, Ill.

[2] **For detailed specifications for these sieves, see the Standard Specifications for Sieves for Testing Purposes (Serial Designation: E 11) of the American Society for Testing Materials, 1927 Book of A.S.T.M. Standards, Part II, p. 917.**

7. Each laboratory sample shall immediately be placed in an air-tight container and shipped to the laboratory for test. **Laboratory Samples.**

METHODS OF TESTING

8. The chemical and physical properties of Keene's cement shall be determined in accordance with the Standard Methods of Testing Gypsum and Gypsum Products (Serial Designation: C 26) of the American Society for Testing Materials.[1] **Methods of Testing.**

PACKING AND MARKING

9. The cement may be shipped in either packages or in bulk. **Packing and Marking.**

(*a*) When shipped for resale, the following information shall be legibly marked on each package or on a tag of suitable size attached thereto:

Name of manufacturer;
Brand;
Description;
Net weight of package.

(*b*) When shipped in bulk, a card containing the required information shall be conspicuously placed in the carrier.

INSPECTION AND REJECTION

10. Inspection may be made either at the point of shipment or at the point of delivery. The inspector representing the purchaser shall have free access to the carriers being loaded for shipment to the purchaser. He shall be afforded all reasonable facilities for inspection and sampling, which shall be so conducted as not to interfere unnecessarily with the loading of the carriers. **Inspection.**

11. Any rejection shall be based upon the specific cause of failure to conform to the requirements of these specifications and shall be reported within ten working days from the receipt of the shipment by the consignee. **Rejection.**

12. Claims for rehearing shall be valid only if made within twenty working days from receipt of notice of specific cause for rejection. **Rehearing.**

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 94.

APPENDIX

FIELD TEST FOR KEENE'S CEMENT

In many instances it is desirable to have a simple test whereby Keene's cement may be identified. Such a test will not indicate the quality of the cement, which should be determined by the laboratory tests enumerated in the body of these specifications but is of especial value to plasterers, material dealers and superintendents.

The following procedure is satisfactory for this purpose:

Take a cupful of the material; mix with water to the consistency of a thick paste and pour upon a plate or piece of glass. Let stand until fairly firm and definite signs of set having begun are manifest. This will be some time less than two hours, depending on climatic conditions.

Divide the sample, allowing one-half to remain undisturbed. Take the other half and break it down, adding a little water; remix, and then allow it to "set up" again on the plate or glass.

If the material is Keene's cement, the remixed portion will, within a few hours, become quite as hard and strong as the portion that was not remixed.

TENTATIVE SPECIFICATIONS
FOR
CALCINED GYPSUM FOR USE IN THE PREPARATION OF DENTAL PLASTERS[1]

Serial Designation: C 72 – 28 T

This is a Tentative Standard, published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1928.

Scope. 1. Calcined gypsums for use in the preparation of dental plasters are products of specific properties with reference to time of set, fineness and water-carrying capacity. These specifications cover two grades:

Grade Q (quick setting).—For use in the preparation of dental impression plaster;

Grade S (slow setting).—For use in the preparation of dental-model and investment plasters.

REQUIREMENTS

Composition. 2. Calcined gypsum for use in the preparation of dental plasters shall contain not less than 93 per cent of calcined gypsum ($CaSO_4 \cdot \frac{1}{2} H_2O$).

Time of Setting. 3. (*a*) *Grade Q.*—The calcined gypsum for use in the preparation of dental impression plaster shall set in not less than 2 nor more than 4 minutes.

(*b*) *Grade S.*—The calcined gypsum for use in the preparation of dental-model and investment plasters shall set in not less than 6 nor more than 12 minutes.

Tensile Strength. 4. The calcined gypsum, when tested in accordance with the requirements of Section 9, shall have a tensile strength of not less than 300 lb. per sq. in.

Fineness. 5. The calcined gypsum shall all pass a No. 30 sieve and not less than 95 per cent shall pass a No. 100 sieve.

Condition. 6. The calcined gypsum shall be dry and free from lumps.

SAMPLING

Sampling. 7. At least 3 per cent of the packages shall be sampled and shall be so selected as to be representative of the contents of the shipment.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. H. J. Schweim, Secretary of Committee C-11 on Gypsum, United States Gypsum Co., 300 W. Adams St., Chicago, Ill.

Samples shall be taken from both the surface and the center of each package so selected. The material so obtained shall be thoroughly mixed and reduced by quartering to provide not less than a 15-lb. (6.75 kg.) sample for the laboratory.

Laboratory Samples.

8. All laboratory samples shall immediately be placed in an air-tight container and shipped to the laboratory for test.

METHODS OF TESTING

Methods of Testing.

9. The chemical and physical properties of calcined gypsum for use in the preparation of dental plasters shall be determined in accordance with the Standard Methods of Testing Gypsum and Gypsum Products (Serial Designation: C 26) of the American Society for Testing Materials,[1] except that in the determinations of the time of set and the tensile strength, the calcined gypsum and water shall be mixed in the proportion of 100 g. of calcined gypsum to 60 cc. of water.

NOTE.—The water used for mixing the calcined gypsum shall be fresh, pure and clean. Trouble may occur from the presence of any excessive amount of mineral or organic substances in the water.

PACKING AND MARKING

Packing and Marking.

10. When shipped, the following information shall be legibly marked on each package or on a tag of suitable size attached thereto:

Name of manufacturer;
Brand;
Description;
Net weight of package.

INSPECTION AND REJECTION

Inspection.

11. Inspection may be made either at the point of shipment or at the point of delivery. The inspector representing the purchaser shall have free access to the carrier being loaded for shipment to the purchaser. He shall be afforded all reasonable facilities for inspection and sampling, which shall be so conducted as not to interfere unnecessarily with the loading of the carriers.

Rejection.

12. Any rejection shall be based upon the specific cause of failure to conform to the requirements of these specifications and shall be reported within ten working days from the receipt of the shipment by the consignee.

Rehearing.

13. Claim for rehearing shall be valid only if made within 20 working days from receipt of notice of specific cause for rejection.

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 94.

TENTATIVE DEFINITIONS OF TERMS RELATING TO THE GYPSUM INDUSTRY[1]

Serial Designation: C 11 - 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1916; REVISED, 1921, 1922, 1923, 1924, 1925, 1926, 1927, 1928.

Aggregate.—Any inert material used as a filler in stucco, plaster, mortar, concrete, etc., without regard to its function as a binding material.

Consistency.—The degree of wetness of a plastic mixture.

Gypsum Plaster Board.—A sheet composed of an incombustible core of gypsum, surfaced with paper or other fibrous material which is firmly bonded to the core, or with intermediate layers of such material within the core, or an incombustible sheet of gypsum with not more than 15 per cent by weight of fiber intimately mixed; and designed to be used as a lath for the reception of gypsum plaster.

Gypsum Wall Board.—A sheet composed of an incombustible core of gypsum, surfaced with paper or other fibrous material which is firmly bonded to the core, and designed to be used, without the addition of plaster, for walls, ceilings or partitions and affording a surface suitable to receive decoration.

Plasticity.—The yielding property of a wet mixture to change of form.

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[1] Criticisms of these Tentative Definitions are solicited and should be directed to Mr. H. J. Schweim, Secretary of Committee C-11 on Gypsum, United States Gypsum Co., 300 W. Adams St., Chicago, Ill.

These Definitions, when adopted as standard, will be added to the present Standard Definitions of Terms Relating to the Gypsum Industry (Serial Designation: C 11 - 28), 1928 Supplement to Book of A.S.T.M. Standards, p. 92.

TENTATIVE SPECIFICATIONS
FOR
CONCRETE AGGREGATES[1]

Serial Designation: C 33 – 28 T

This is a **Tentative Standard**, published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1921; REVISED, 1923, 1926, 1928.

QUALITY OF AGGREGATES

It is recognized that for certain purposes satisfactory results may be obtained with materials not conforming to these specifications. In such cases the use of fine and coarse aggregates not conforming to these specifications should be authorized only under special provisions based upon laboratory studies of the possibility of designing a mixture of materials to be used on the job that will yield concrete equivalent to the specified mixture made with material complying with these specifications in all respects.

FINE AGGREGATE

General Characteristics. 1. Fine aggregate shall consist of sand or other approved inert materials with similar characteristics, or a combination thereof, having hard, strong, durable particles and shall conform to the requirements of these specifications.

Deleterious Substances. 2. (*a*) The maximum percentages of deleterious substances shall not exceed the following values:

	PER CENT BY WEIGHT
Removed by decantation	3
Shale	1
Coal	1
Clay lumps	1
Other local deleterious substances (such as alkali, mica, coated grains, soft and flaky particles)	....

NOTE.—It is recognized that under certain conditions maximum percentages of deleterious substances less than those shown in the table should be specified.

(*b*) The sum of the percentages of shale, coal, clay lumps, soft fragments and other deleterious substances shall not exceed 5 per cent by weight.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. Stanton Walker, Secretary of Committee C-9 on Concrete and Concrete Aggregates, 837 Munsey Building, Washington, D. C.

(*c*) All fine aggregate shall be free from injurious amounts of organic impurities. Aggregates subjected to the colorimetric test for organic impurities and producing a color darker than the standard shall be rejected unless they pass the mortar strength test as specified in Section 4.

Grading.

3. (*a*) Fine aggregate shall be well graded from coarse to fine and when tested by means of laboratory sieves[1] shall conform to the following requirements:

	PER CENT
Passing a ⅜-in. sieve	100
Passing a No. 4 sieve	(85) to (100)
Passing a No. 16 sieve	(45) to (80)
Passing a No. 50 sieve	(2) to (30)
Passing a No. 100 sieve	(0) to (5)

NOTE.—Figures in parentheses are suggested as limiting percentages but they may be altered within these limits to suit local conditions.

(*b*) In case the concrete resulting from a mixture of aggregates approaching the extreme limits for gradation is not of a workable character, or when finished does not exhibit a proper surface, due to an excess of particles approximately ⅛ to ½ in. in size, either a fine aggregate having a sufficiently greater percentage of fine material, or a coarse aggregate having a sufficiently smaller percentage of fine material must be used.

Mortar Strength.

4. Fine aggregates, when subjected to the mortar strength test, shall have a tensile or compressive strength at the age of 7 and 28 days of not less than (100)[2] per cent of that developed by mortar of the same proportions and consistency made of the same cement and standard Ottawa sand.

COARSE AGGREGATE

General Characteristics.

5. Coarse aggregate shall consist of crushed stone, gravel, blast-furnace slag, or other approved inert materials of similar characteristics, or combinations thereof, having hard, strong, durable pieces, free from adherent coatings and conforming to the requirements of these specifications.

Deleterious Substances.

6. (*a*) The maximum percentages of deleterious substances shall not exceed the following values:

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[1] For detail requirements for these sieves, see the Standard Specifications for Sieves for Testing Purposes (Serial Designation: E 11) of the American Society for Testing Materials, 1927 Book of A.S.T.M. Standards, Part II, p. 917.

[2] Percentages in parentheses are recommended but they may be altered to suit local conditions.

	PER CENT BY WEIGHT
Removed by decantation	1
Shale	1
Coal	1
Clay lumps	½
Soft fragments	5
Other local deleterious substances (such as alkali, friable, thin, elongated, or laminated pieces)	....

NOTE.—It is recognized that under certain conditions maximum percentages of deleterious substances less than those shown in the table should be specified.

(*b*) The sum of the percentages of shale, coal, clay lumps and soft fragments shall not exceed 5 per cent by weight.

Grading. 7. (*a*) Coarse aggregate shall be well graded, between the limits specified, and shall conform to the following requirements:

		PER CENT BY WEIGHT
Passing .... in. Sieve[1] or Screen	(maximum size)	not less than (95)
Passing .... in. Sieve[1] or Screen	(intermediate size)	not less than (40)
	(one-half maximum size)	not more than (75)
Passing .... in. Sieve[1] or Screen	(intermediate sizes)	not less than ....
	(as needed)	not more than ....
Passing No. 4 Sieve or a ¼-in. Screen		not more than (10)

NOTE.—Where a range is shown the engineer should use an appropriate figure within the limits recommended. The percentages in parentheses are recommended but may need to be altered to suit local conditions.

(*b*) In case the concrete resulting from a mixture of aggregates approaching the extreme limits for gradation is not of a workable character, or when finished does not exhibit a proper surface, due to an excess of particles approximately ⅛ to ½ in. in size, either a fine aggregate having a sufficiently greater percentage of fine material, or a coarse aggregate having a sufficiently smaller percentage of fine material shall be used.

Weight of Slag. 8. Blast-furnace slag that meets the grading requirements of these specifications shall conform to the following minimum weight requirements:

Base concrete	65 lb. per cu. ft.
Surface concrete (subject to abrasion)	70 lb. per cu. ft.

Durability. 9. Coarse aggregate shall pass a sodium sulfate accelerated soundness test, except that aggregates failing in the accelerated soundness test may be used if they pass a satisfactory freezing and thawing test.

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[1] The question whether round or square openings shall be used for testing aggregates is now being studied by the Section on Coarse Screens of the Technical Committee on Size and Shape of Committee E-1 on Methods of Testing.

NOTE.—Many engineers feel that an abrasion test for coarse aggregate to be used in concrete subject to abrasion is important, but no test limits are specified, due to the status of knowledge concerning suitable specification limits for this test.

METHODS OF SAMPLING AND TESTING

Methods of Testing.

10. The properties enumerated in these specifications shall be determined in accordance with the following methods of test of the American Society for Testing Materials, except as specified in Paragraph (*e*).

(*a*) *Sampling.*—Standard Methods of Sampling Stone, Slag, Gravel, Sand and Stone Block for Use as Highway Materials, Including Some Material Survey Methods (Serial Designation: D 75).[1]

(*b*) *Sieve Analysis.*—Standard Method of Test for Sieve Analysis of Aggregates for Concrete (Serial Designation: C 41).[2]

(*c*) *Decantation Test.*—Standard Method of Decantation Test for Sand and Other Fine Aggregates (Serial Designation: D 136).[3]

(*d*) *Organic Impurities.*—Standard Method of Test for Organic Impurities in Sands for Concrete (Serial Designation: C 40).[4]

(*e*) *Mortar Strength.*—Methods of Making Compression and Tension Tests of Fine Aggregate for Concrete as adopted by the American Association of State Highway Officials.

(*f*) *Compressive Strength.*—Standard Methods of Making Compression Tests of Concrete (Serial Designation: C 39).[5]

(*g*) *Soundness.*—Proposed Method of Test for Soundness of Coarse Aggregate (Sodium Sulfate Soundness Test), Appendix II to 1928 Report of Committee C-9 on Concrete and Concrete Aggregates.[6]

(*h*) *Freezing and Thawing.*—Method of Freezing and Thawing Tests of Drain Tile as described in the Standard Specifications for Drain Tile (Serial Designation: C 4).[7]

(*i*) *Shale and Coal.*—Proposed Method of Test for Percentage of Shale in Aggregate, Appendix III to 1928 Report of Committee C-9 on Concrete and Concrete Aggregates.[6]

(*j*) *Soft Fragments.*—Proposed Method of Test for Quantity of Soft Pebbles in Gravel, Appendix IV to 1928 Report of Committee C-9 on Concrete and Concrete Aggregates.[6]

(*k*) *Coal and Lignite.*—Proposed Method of Test for Determination of Coal and Lignite in Sand, Appendix V to 1928 Report of Committee C-9 on Concrete and Concrete Aggregates.[6]

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 473.

[2] *Ibid.*, p. 124.

[3] 1928 Supplement to Book of A.S.T.M. Standards, p. 161.

[4] 1927 Book of A.S.T.M. Standards, Part II, p. 123.

[5] *Ibid*, p. 112.

[6] See p. 341.

[7] 1927 Book of A.S.T.M. Standards, Part II, p. 190

(*l*) *Moisture.*—Tentative Method of Test for Field Determination of Surface Moisture in Fine Aggregate (Serial Designation: C 70 - 28 T).[1]

(*m*) *Consistency.*—Tentative Method of Test for Consistency of Portland-Cement Concrete (Serial Designation: D 138 - 26 T).[2]

(*n*) *Weight of Slag.*—Standard Method of Test for Unit Weight of Aggregate for Concrete (Serial Designation: C 29).[3]

(*o*) *Abrasion.*—If abrasion tests are made the following methods of test are recommended:

> (1) *Abrasion of Gravel.*—Tentative Method of Test for Abrasion of Gravel (Serial Designation: D 289 - 28 T).[4]
>
> (2) *Abrasion of Rock or Crushed Slag.*—Standard Method of Test for Abrasion of Rock (Serial Designation: D 2),[5] except that for specific gravities lower than 2.2 a 4000-g. sample shall be used.

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[1] See p. 832.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, p. 874 (1926); also 1928 Book of A.S.T.M. Tentative Standards, p. 518.

[3] 1927 Book of A.S.T.M. Standards, Part II, p. 120.

[4] See p. 940.

[5] 1927 Book of A.S.T.M. Standards, Part II, p. 463.

TENTATIVE METHOD OF TEST
FOR
FIELD DETERMINATION OF APPROXIMATE APPARENT SPECIFIC GRAVITY OF FINE AGGREGATE[1]

Serial Designation: C 68 – 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1927; REVISED, 1928.

Scope.

1. This method of test is intended for use in the field for making approximate determinations of the apparent specific gravity of fine aggregate. The range of the apparatus is between specific gravities of 2.2 and 2.85.

Apparatus.

2. The apparatus shall consist of the following:

(*a*) *Balance.*—A balance, preferably of the torsion type, having a capacity of 2 kg. or more and sensitive to 0.5 g. or less.

(*b*) *Flask.*—A special graduated flask of the type, and conforming to the dimensions, shown in Fig. 1.

Sample.

3. A 1-kg. sample shall be selected which shall be as truly representative of the fine aggregate as possible. It shall be spread out on a flat surface and air dried until the surface moisture has evaporated and the sample is free flowing. The sample shall then be thoroughly mixed and 500 g. accurately weighed out.

Procedure.

4. The graduated flask shall be filled to the 200-cc. mark on the lower neck with water at room temperature. The 500-g. sample of fine aggregate shall then be slowly poured into the flask, and the flask and contents agitated while introducing the aggregate to free any entrained air bubbles. The combined volume in cubic centimeters of the water and fine aggregate shall be read on the scale on the upper neck of the flask.

Interpreting Results.

5. The approximate apparent specific gravity of the fine aggregate may be calculated from the formula:

$$\text{Approximate apparent specific gravity} = \frac{500}{V - 200}$$

where V = the combined volume in cubic centimeters of the water and fine aggregate in the flask.

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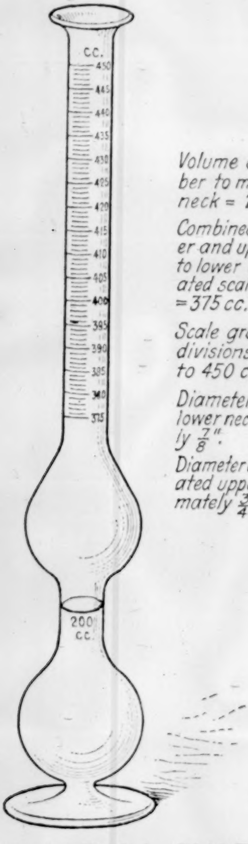
[1] Criticisms of this Tentative Method are solicited and should be directed to Mr. Stanton Walker, Secretary of Committee C-9 on Concrete and Concrete Aggregates, 837 Munsey Building, Washington, D. C.

Accuracy. 6. Duplicate determinations should check to within 0.05. Variations in the amount of water evaporated from the moist sample as described in Section 3 beyond the point at which the surface moisture has disappeared and the sample is free flowing and apparently dry will cause variations in results of from 0.5 to 1 per cent depending upon the absorption of the aggregate.



Volume of lower chamber to mark on lower neck = 200 cc.

Combined volume of lower and upper chambers to lower end of graduated scale on upper neck = 375 cc.

Scale graduated in 1 cc. divisions from 375 cc. to 450 cc.

Diameter of opening in lower neck, approximately $\frac{7}{8}$".

Diameter of bore of graduated upper neck, approximately $\frac{3}{4}$".

FIG. 1.—Graduated Flask for Field Testing of Fine Aggregate.

TENTATIVE METHOD OF TEST
FOR
FIELD DETERMINATION OF APPROXIMATE PERCENTAGE OF VOIDS IN FINE AGGREGATE[1]

Serial Designation: C 69 – 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1927; REVISED, 1928.

Scope. 1. This method of test is intended for use in the field for making approximate determinations of the percentage of voids in fine aggregate when inundated with water.

Apparatus 2. The apparatus shall consist of the following:

(*a*) *Balance.*—A balance, preferably of the torsion type, having a capacity of 2 kg. or more and sensitive to 0.5 g. or less.

(*b*) *Flask.*—A special graduated flask of the type, and conforming to the dimensions, shown in Fig. 1.

Sample. 3. A sample weighing about 2 kg. shall be selected which shall be as truly representative of the fine aggregate as possible. It shall be well mixed and spread out on a flat surface and air dried until the surface moisture has evaporated and the sample is free flowing.

Procedure. 4. About 100 cc. of water shall be placed in the flask. Aggregate from the room-dry sample shall then be introduced slowly into the flask until the flask is filled to the 400-cc. mark on the upper neck. Water shall be added as required to keep the aggregate inundated as the filling proceeds. When the flask is filled to the 400-cc. mark, both water and aggregate shall be at the same level. The aggregate in the flask shall not be agitated during or after the filling operation. The flask and contents shall be weighed to the nearest gram, and the weight of the flask shall be deducted, unless its weight has been counter-balanced on the scale at the time of weighing.

Interpreting Results. 5. (*a*) This method requires that the apparent specific gravity be known of the fine aggregate in a room-dry, free flowing condition, but with the voids within the particles of the aggregate containing moisture. If the apparent specific gravity of the aggregate in this condition is not known it shall be determined in accordance with the Tentative Method of Test for Field Determination of Approximate Apparent Specific Gravity of Fine Aggregate (Serial Designation: C 68 - 28 T) of the American Society for Testing Materials.[1]

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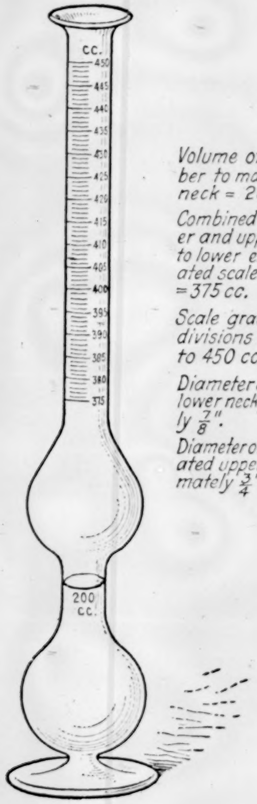
[1] Criticisms of this Tentative Method are solicited and should be directed to Mr. Stanton Walker, Secretary of Committee C-9 on Concrete and Concrete Aggregates, 837 Munsey Building, Washington, D. C.



Volume of lower chamber to mark on lower neck = 200 cc.

Combined volume of lower and upper chambers to lower end of graduated scale on upper neck = 375 cc.

Scale graduated in 1 cc. divisions from 375 cc. to 450 cc.

Diameter of opening in lower neck, approximately $\frac{7}{8}$".

Diameter of bore of graduated upper neck, approximately $\frac{3}{4}$".

FIG. 1.—Graduated Flask for Field Testing of Fine Aggregate.

(*b*) The approximate percentage of voids in the inundated fine aggregate may be calculated from the formula:

$$V = \frac{400 \times \text{sp. gr.} - W}{400\ (\text{sp. gr.} - 1)} \times 100$$

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[1] See p. 827.

where V = the approximate percentage of voids;
sp. gr. = apparent specific gravity of the fine aggregate;
W = combined weight in grams of 400 cc. of water and fine aggregate in the flask.

Accuracy.

6. Duplicate determinations should check to within 1 per cent. Variations in the composition of the rock grains of the fine aggregate which result in variations of 0.05 in the approximate apparent specific gravity of the aggregate will cause an inaccuracy in results equal to from 2 to 3 per cent of voids.

TENTATIVE METHOD OF TEST
FOR
FIELD DETERMINATION OF SURFACE MOISTURE IN FINE AGGREGATE[1]

Serial Designation: C 70 - 28 T

This is a Tentative Standard, published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1927; REVISED, 1928.

Scope. 1. This method of test is intended for use in the field for making approximate determinations of the percentage of surface moisture in fine aggregate for use in computing the allowance to be made for water in the fine aggregate when proportioning concrete by the maximum water content method. The range of the apparatus is between the specific gravities of 2.2 for aggregate containing 10 per cent moisture and 2.85 for dry aggregate.

This method determines only surface moisture, that is, moisture on the outside of the particles. The moisture absorbed within the particles does not add to the volume of the particles and, therefore, does not make itself evident in this test.

Apparatus. 2. The apparatus shall consist of the following:

(*a*) *Balance.*—A balance, preferably of the torsion type, having a capacity of 2 kg. or more and sensitive to 0.5 g. or less.

(*b*) *Flask.*—A special graduated flask of the type, and conforming to the dimensions, shown in Fig. 1.

Sample. 3. A sample weighing about 1 kg. shall be selected which shall be as truly representative of the fine aggregate as possible. It shall be well mixed and spread out on a flat non-absorbent surface. Five hundred grams shall be immediately weighed out, permitting moisture to evaporate as little as possible from the sample.

Procedure. 4. The graduated flask shall be filled to the 200-cc. mark on the lower neck with water at room temperature. The 500-g. sample of damp aggregate shall then be slowly poured into the flask, and the contents of the flask agitated or stirred to free any entrained air bubbles. The combined volume, in cubic centimeters, of the water and fine aggregate shall be read on the scale on the upper neck of the flask.

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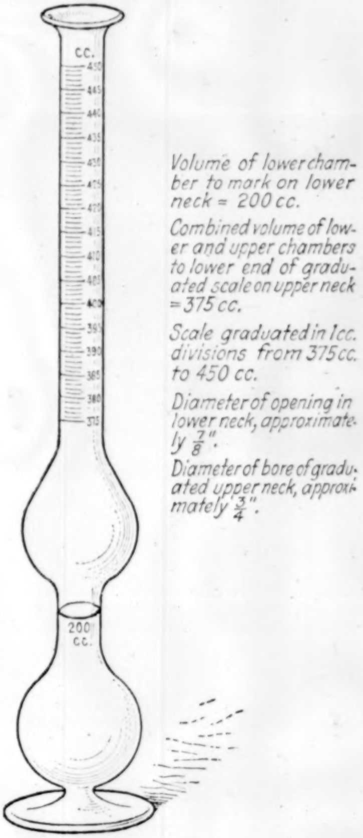
[1] Criticisms of this Tentative Method are solicited and should be directed to Mr. Stanton Walker, Secretary of Committee C-9 on Concrete and Concrete Aggregates, 837 Munsey Building, Washington, D. C.

Interpreting Results.

5. (*a*) This method requires that the apparent specific gravity be known of the fine aggregate in a room-dry, free flowing condition, but with the voids within the particles of the aggregate containing moisture. If the apparent specific gravity of the aggregate in this condition is not known it shall be determined in accordance with the Tentative Method of Test for Field Determination of Approximate Apparent Specific Gravity of Fine Aggregate (Serial Designation: C 68 - 28 T) of the American Society for Testing Materials.[1]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200 cc.
Volume of lower chamber to mark on lower neck = 200 cc.
Combined volume of lower and upper chambers to lower end of graduated scale on upper neck = 375 cc.
Scale graduated in 1cc. divisions from 375cc. to 450 cc.
Diameter of opening in lower neck, approximately 7/8".
Diameter of bore of graduated upper neck, approximately 3/4".

FIG. 1.—Graduated Flask for Field Testing of Fine Aggregate.

(*b*) The percentage of surface moisture in the fine aggregate (air dry basis) may be calculated from the formula:

$$\text{Percentage of surface moisture} = \frac{V - \dfrac{500}{\text{sp. gr.}} - 200}{200 + 500 - V} \times 100$$

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[1] See p. 827.

where V = the combined volume in cubic centimeters of the water and fine aggregate in the flask;

sp. gr. = approximate apparent specific gravity of the fine aggregate.

Accuracy. 6. Duplicate determinations should check to within 0.5 per cent. Variations in the composition of the rock grains of the fine aggregate which result in variations of 0.05 in the approximate apparent specific gravity of the aggregate will cause inaccuracy in results equal to from 1 to 1.5 per cent of moisture.

TENTATIVE DEFINITION OF THE TERM AGGREGATE[1]

Serial Designation: C 58 - 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1926; REVISED, 1928.

Aggregate.—In the case of materials of construction, designated inert material, which when bound together into a conglomerated mass by a matrix forms concretes, mastic, mortar, plaster, etc.

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[1] Criticisms of this Tentative Definition are solicited and should be directed to Mr. L. R. Ferguson, Chairman of the Sub-Committee, of Committee E-8, on Definition of Sand and Aggregate, Texas Portland Cement Co., 1401 Santa Fe Building, Dallas, Tex.

This Tentative Definition, when adopted as standard, will be added to the present Standard Definition of the Term Sand (Serial Designation: C 58 - 28), 1928 Supplement to Book of A.S.T.M. Standards, p. 95.

TENTATIVE SPECIFICATIONS
FOR
BUILDING BRICK
(MADE FROM CLAY OR SHALE)[1]

Serial Designation: C 62 – 28 T

This is a Tentative Standard, published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1927; REVISED, 1928.

Scope. 1. These specifications cover brick made from clay or shale and properly burned, intended for use in brick masonry.

PHYSICAL PROPERTIES AND TESTS

Physical Properties and Tests. 2. (*a*) The bricks shall be classified as Grades *A*, *B*, and *C* on the basis of the following requirements. The classification of any lot of bricks shall be determined by the results of the tests for that requirement in which it is lowest, unless otherwise specified as provided in Section 8:

Name of Grade	Compressive Strength (bricks flatwise), lb. per sq. in.		Modulus of Rupture (bricks flatwise) lb. per sq. in.	
	Mean of 5 Tests	Individual Minimum	Mean of 5 Tests	Individual Minimum
Grade A	4500 or over	3500	600 or over	400
Grade B	2500-4500	2000	450 " "	300
Grade C	1250-2500	1000	300 " "	200

NOTE.—The above classifications are based on strength and do not necessarily measure weather resistance.

(*b*) The tests shall be conducted in accordance with the Tentative Methods of Testing Brick (Serial Designation: C 67 – 28 T), of the American Society for Testing Materials.[2]

Test Specimens. 3. For the purpose of tests, bricks representative of the commercial product shall be selected by a competent person appointed by the purchaser, the place or places of selection to be designated when the purchase order is placed. The manufacturer or seller shall furnish specimens for tests without charge. All bricks shall be carefully examined and their condition noted before testing. For the purpose of tests, not less than ten brick shall be required for each investigation. In general, two samples of ten brick each shall be tested for every 100,000 bricks contained in the lot under consideration; but where the total quantity exceeds 500,000, the number of samples tested may be fewer, provided that they shall be distributed as uniformly as practicable over the entire lot. Additional representative samples may be taken at any time or place at the discretion of the purchaser.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. J. W. McBurney, Secretary of Committee C-3 on Brick, U. S. Bureau of Standards, Washington, D. C.

These Tentative Specifications are in effect a revision of the former Standard Specifications for Building Brick (Serial Designation: C 21 – 24) which were accordingly discontinued in 1927.

[2] See p. 854.

STANDARD SIZES

4. The standard sizes shall conform to the following dimensions, with a permissible variation, plus or minus, of $\frac{1}{16}$ in. in depth, $\frac{1}{8}$ in. in width, and $\frac{1}{4}$ in. in length: **Standard Sizes.**

TYPE	DEPTH, IN.	WIDTH, IN.	LENGTH, IN.
Common brick	$2\frac{1}{4}$	$3\frac{3}{4}$	8
Rough-face brick	$2\frac{1}{4}$	$3\frac{3}{4}$	8
Smooth-face brick	$2\frac{1}{4}$	$3\frac{7}{8}$	8

WORKMANSHIP AND FINISH

5. When any particular surface appearance or uniformity is desired, it shall be as mutually agreed upon. **Surface Appearance.**

INSPECTION AND REJECTION

6. All brick shall comply with the following requirements for general properties under visual inspection: **Visual Inspection.**

(*a*) They shall be free from cracks, warpage, stones, pebbles, or particles of lime that would affect their serviceability or strength.

(*b*) Bricks of Grades *A* or *B* when struck together shall give a ringing sound.

7. If the visual inspection, Section 6, appears to indicate inferior strength, the brick may be rejected unless the physical tests show the quality or grade to be as specified. **Rejection.**

8. At the option of the purchaser, acceptance may be based on the visual inspection requirements specified in Section 6 and the results of one of the strength tests (compression or flexure) specified in Section 2. While the compressive strength is considered as generally giving the better basis for classification purposes, the flexure test gives important information on the strength and proper manufacturing details. **Acceptance.**

TENTATIVE SPECIFICATIONS
FOR
CONCRETE BUILDING BRICK[1]

Serial Designation: C 55 – 28 T

This is a Tentative Standard, published for the purpose of eliciting criticism **and suggestions,** and as such is subject to annual revision.

ISSUED, 1924; REVISED, 1928.

Scope. 1. These specifications cover concrete building brick intended for use in brick masonry.

Manufacture. 2. Concrete building brick shall be manufactured from a mixture of portland cement and suitable aggregate.

PHYSICAL PROPERTIES AND TESTS

Physical Properties and Tests. 3. (*a*) Concrete building brick shall be classified as Grades B and C on the basis of the following requirements. The classification of any lot of bricks shall be determined by the results of the tests for that requirement in which it is lowest, unless otherwise specified as provided in Section 7.

Classification	Compressive Strength (brick flatwise), lb. per sq. in.		Modulus of Rupture (brick flatwise), lb. per sq. in.	
	Mean of 5 Tests	Individual Minimum	Mean of 5 Tests	Individual Minimum
Grade B	2250	1500	450	300
Grade C	1250	1000	300	200

NOTE.—The above classifications are based on strength and do not necessarily measure weathering resistance.

Test Specimens. (*b*) The tests shall be made in accordance with the Tentative Methods of Testing Brick (Serial Designation: C 67 – 28 T) of the American Society for Testing Materials.[2]

4. (*a*) For the purpose of tests, bricks representative of the commercial product shall be selected by a competent person appointed

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. J. W. McBurney, Secretary of Committee C-3 on Brick, U. S. Bureau of Standards, Washington, D. C.

[2] See p. 854.

by the purchaser, the place or places of selection to be designated when the purchase order is placed. The manufacturer or seller shall furnish specimens for tests without charge. All bricks shall be carefully examined and their condition noted before testing. For the purpose of tests, not less than ten bricks shall be required for each investigation. In general, two samples of ten bricks each shall be tested for every 100,000 bricks contained in the lot under consideration; but where the total quantity exceeds 500,000, the number of samples tested per 100,000 bricks may be fewer, provided that they shall be distributed as uniformly as practicable over the entire lot. Additional representative samples may be taken at any time or place at the discretion of the purchaser.

(*b*) Concrete building brick when sampled at the plant shall be at least 28 days old, unless otherwise mutually agreed upon between the manufacturer and the purchaser. Representative samples may be taken at any time by the purchaser from brick delivered on the job.

STANDARD SIZE

Standard Size.

5. The standard size of concrete building brick shall be $2\frac{1}{4}$ by $3\frac{3}{4}$ by 8 in. with a permissible variation of plus or minus $\frac{1}{16}$ in. in depth, $\frac{1}{8}$ in. in width and $\frac{1}{4}$ in. in length.

VISUAL INSPECTION AND REJECTION

Inspection and Rejection.

6. Brick shall pass a visual inspection for freedom from cracks and irregularity. Cracked or mis-shaped brick shall be rejected.

Acceptance.

7. At the option of the purchaser, acceptance may be based on the visual inspection requirements specified in Section 6 and on the results of one of the strength tests (compressive or flexure) specified in Section 3.

TENTATIVE SPECIFICATIONS
FOR
SAND-LIME BUILDING BRICK[1]

Serial Designation: C 73 – 28 T

This is a Tentative Standard, published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1928.

Scope.

1. These specifications cover building brick made from sand and lime intended for use in brick masonry.

PHYSICAL PROPERTIES AND TESTS

Physical Properties and Tests.

2. (*a*) The bricks shall be classified as Hard, Medium and Soft on the basis of the following requirements. The classification of any lot of bricks shall be determined by the results of the tests for that requirement in which it is lowest.

Classification	Absorption Limits, per cent		Modulus of Rupture (brick flatwise), lb. per sq. in.	
	Mean of 5 Tests	Individual Maximum	Mean of 5 Tests	Individual Minimum
Hard	9 or less	12	600 or over	400
Medium	9 to 15	18	450 or over	300
Soft	15 or over	No limit	300 or over	200

Test Specimens.

(*b*) The tests shall be made in accordance with the Tentative Methods of Testing Brick (Serial Designation: C 67 – 28 T) of the American Society for Testing Materials.[2]

3. For the purpose of tests, bricks representative of the commercial product shall be selected by a competent person appointed by the purchaser, the place or places of selection to be designated when the purchase order is placed. The manufacturer or seller shall furnish specimens for test without charge. All bricks shall be carefully examined and their condition noted before testing. For the purpose of tests, not less than ten bricks shall be required. In general, two samples of ten bricks each shall be tested for every 100,000

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. J. W. McBurney, Secretary of Committee C-3 on Brick, U. S. Bureau of Standards, Washington, D. C.

[2] See p. 854.

bricks contained in the lot under consideration; but where the total quantity exceeds 500,000, the number of samples tested per 100,000 bricks may be fewer, provided that they shall be distributed as uniformly as practicable over the entire lot. Additional representative samples may be taken at any time or place at the discretion of the purchaser.

STANDARD SIZE

Standard Size. 4. The standard size of sand-lime brick shall be $2\frac{1}{4}$ by $3\frac{3}{4}$ by 8 in. with a permissible variation of plus or minus $\frac{1}{16}$ in. in depth, $\frac{1}{8}$ in. in width and $\frac{1}{4}$ in. in length.

INSPECTION AND REJECTION

Visual Inspection. 5. All bricks shall conform to the following requirements for general properties under visual inspection:

(*a*) They shall be sound, of compact structure, reasonably uniform in shape and free from cracks, warpage, large pebbles, balls of clay, or particles of lime that would affect their serviceability or strength. After being subjected to the absorption test they shall show no superficial disintegration.

Rejection. 6. If the visual inspection, Section 5, appears to indicate inferior strength, the bricks may be rejected unless the physical tests show the quality or grade to be as specified.

TENTATIVE SPECIFICATIONS
FOR
PAVING BRICK[1]

Serial Designation: C 7 - 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

Issued, 1927; Revised, 1928.

Scope. 1. These specifications cover all styles of vitrified paving brick used in the construction of pavements, and classified as follows:

Class A: Vitrified Paving Brick.—The sizes and varieties recognized by the Permanent Committee on Simplification of Varieties and Styles for Vitrified Paving Brick of the U. S. Department of Commerce, as follows:

	Depth, in.	Width, in.	Length, in
Plain Wire-Cut (vertical fiber lugless as usually laid)	2½ 3 3½	4 4 4	8½ 8½ 8½
Wire-Cut Lug (Dunn)	4	3½	8½
Repressed Lug	4	3½	8½

Note.—The above sizes and varieties are those recognized by the Permanent Committee, for the year 1927, and are subject to change from year to year.

Class B: Vitrified Paving Brick.—All other sizes and varieties.

Basis of Purchase. 2. The consumer or purchaser shall specify the class and variety or size, or the classes and varieties or sizes of paving brick to be supplied.

MANUFACTURE

Manufacture. 3. Paving brick shall be manufactured from fire clay or shale, or a combination thereof, molded into the requisite shape and properly vitrified.

PHYSICAL PROPERTIES AND TESTS

Rattler Test. 4. (*a*) The quality and acceptability of paving brick, shall be determined by the Rattler Test, as described in Sections 16 to 29, inclusive.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. J. W. McBurney, Secretary of Committee C-3 on Brick, U. S. Bureau of Standards, Washington, D. C.

These tentative specifications, when adopted as standard, will supersede the present Standard Specifications for Paving Brick (Serial Designation: C 7 - 15), 1927 Book of A.S.T.M. Standards, Part II, p. 126.

(*b*) A visual inspection shall be made for the purpose of determining whether the physical properties of the brick as to dimensions, accuracy, and uniformity of shape and color, are in general satisfactory as well as for the purpose of culling out from the shipment individually imperfect or unsatisfactory brick. **Visual Inspection.**

(*c*) The acceptance of paving brick as satisfactorily meeting one of these tests shall not be construed as in any way waiving the other.

5. The average percentage of loss when determined in accordance with the Rattler Test shall not exceed 22 per cent. **Percentage of Loss.**

SAMPLING

6. The standard test sample of paving brick of any size shall be ten brick. **Standard Test Sample.**

7. In general, where a shipment of brick involving a quantity of less than 100,000 is under consideration, the sampling may be done either at the brick factory prior to shipment, on cars at their destination, or on the street when delivered ready for use. When the quantity under consideration exceeds 100,000, the sampling shall be done at the factory prior to shipment. Brick accepted as the result of test prior to shipment shall not be liable to subsequent rejection as a whole, but are subject to culling as specified in Section 13. **Place of Sampling.**

8. In general, the buyer shall select his own samples from the material which the seller proposes to furnish. The seller shall have the right to be present during the selection of a sample. The sampler shall endeavor, to the best of his judgment, to select brick representing the average of the lot. No samples shall include bricks which would be rejected by visual inspection as provided in Section 13, except that where controversy arises, whole tests may be selected to determine the admissibility of certain varieties or portions of the lot having a characteristic appearance in common. In cases where prolonged controversy occurs between buyer and seller and samples selected by each party fail to show reasonable concurrence, then both parties shall agree on a disinterested person to select the samples, and both parties shall be bound by the results of tests made on samples thus selected. **Selecting Samples.**

9. In general, one sample of ten brick shall be tested for every 10,000 bricks contained in the lot under consideration, but where the total quantity exceeds 100,000, the number of samples tested may be fewer than one per 10,000, provided that they shall be distributed as uniformly as practicable over the entire lot. **Number of Samples.**

10. Samples which must be transported long distances by freight or express shall be carefully put in packages holding not more than **Shipment of Samples.**

twelve bricks each. When more than six bricks are shipped in one package, it shall be so arranged as to carry two parallel rows of bricks side by side, and these rows shall be separated by a partition. In the event of some of the bricks being cracked or broken in transit, the sample shall be disqualified if there are not remaining ten sound undamaged bricks.

Storage and Care of Samples.

11. Samples shall be carefully handled to avoid breakage or injury. They shall be kept in the dry so far as practicable. If they are wet when received, or known to have been immersed or subjected to recent prolonged wetting, they shall be dried for at least six hours at a temperature of 38° C. (100° F.) before testing.

SIZE AND PERMISSIBLE VARIATIONS

Size and Permissible Variations.

12. Paving brick shall conform to the following size requirements, subject to plus or minus variations of ⅛ in. in width and depth, and ½ in. in length:

	Depth, in.	Width, in.	Length, in.
Class B Brick			
Minimum	2	3	8½
Maximum	4	4	9
Class A Brick			
Minimum	2½	3½	8½
Maximum	4	4	8½

INSPECTION AND REJECTION

Inspection and Rejection.

13. It shall be the right of the buyer to inspect the bricks, subsequent to their delivery at the place of use, and prior to or during laying, to cull out and reject upon the following grounds:

(*a*) All brick which are broken in two or chipped in such a manner that neither wearing surface remains substantially intact, or that the lower or bearing surface is reduced in area by more than one-fifth. Where bricks are rejected upon this ground, it shall be the duty of the purchaser to use them in so far as practicable in obtaining the necessary half-bricks for breaking courses and making closures, instead of breaking otherwise whole and sound bricks for this purpose.

(*b*) All brick which are cracked in such a degree as to produce defects such as are defined in Paragraph (*a*), either from shocks received in shipment and handling, or from defective conditions of manufacture, especially in drying, burning or cooling, unless such cracks are plainly superficial and not such as to perceptibly weaken the resistance of the brick to its conditions of use.

(*c*) All brick which are so off-size, or so misshapen, bent, twisted or kiln-marked, that they will not form a proper surface as defined by the paving specifications, or align with other bricks without making joints other than those permitted in the paving specifications.

(*d*) All brick which are obviously too soft and too poorly vitrified to endure street wear. When any disagreement arises between the buyer and seller under this item, it shall be the right of the buyer to make two or more rattler tests of the brick, which he wishes to exclude, as provided in Section 4 (*a*) and if in either or both tests, the brick fall beyond the maximum rattler losses permitted under the specifications, then all brick having the same objectionable appearance may be excluded, and the seller shall pay the costs of the tests. But, if under such procedure, the bricks which have been tested as objectionable, shall pass the rattler test, the percentage of loss in both tests falling within the permitted maximum, then the buyer cannot exclude the class of material represented by this test and he shall pay the costs of the tests.

(*e*) All brick which differ so markedly in color from the type or average of the shipment, as to make the resultant pavement checkered or disagreeably mottled in appearance. This requirement shall not be held to apply to the normal variations in color which may occur in the product of one plant among brick which will meet the rattler test as provided in Section 14, but shall apply only to differences of color which imply differences in the material of which the bricks are made, or extreme differences in manufacture.

Rejection Limits.

14. (*a*) Paving brick shall not be judged for acceptance or rejection by the results of individual tests, but by the average of not less than five tests except that where a lot of brick fails to meet the required average, it shall be optional with the buyer whether the brick shall be definitely rejected or whether they may be regraded and a portion selected for further test as provided in Paragraph (*c*).

(*b*) Some fluctuation in the results of the rattler test, both on account of variations in the bricks and in the machine used in testing, are unavoidable and a reasonable allowance for such fluctuation should be made, wherever the standard may be fixed.

(*c*) In any lot of paving brick, if the percentage of loss on a test computed upon its initial weight exceeds the specified loss by more than 2 per cent, then the portion of the lot represented by that test shall at once be re-sampled and three more tests made; and if any of these three tests shall again exceed by more than 2 per cent the specified loss then that portion of the lot shall be rejected.

If, in any lot of brick, the results of two or more tests exceed the permissible maximum, then the buyer may, at his option, reject the entire lot, even though the average of all the tests executed may be within the required limits.

(*d*) Where a lot, or portion of a lot of brick is rejected, either by reason of failure to show a low enough average test or because of tests above the permissible maximum, the buyer may, at his option, permit the seller to regrade the rejected brick, separating out that portion which he considers at fault and retaining that which he considers good. When the regrading is complete, the good portion shall be then re-sampled and retested, under the original conditions, and if it fails again either in average or in permissible maximum, then the buyer may definitely and finally reject the entire lot or portion under test.

Payment of Test Costs. 15. Unless otherwise specified, the cost of testing the material as delivered or prepared for delivery, up to the prescribed number of tests for valid acceptance or rejection of the lot, shall be paid by the buyer. The cost of testing extra samples made necessary by the failure of the whole lot or any portion of it, shall be paid by the seller, whether the material is finally accepted or rejected.

RATTLER TEST

APPARATUS

Apparatus. 16. The machine used in the rattler test shall be of good mechanical construction, self-contained, and shall conform to the following details of material and dimensions, and shall consist of barrel, frame and driving mechanism as described in Sections 17 to 21. In Fig. 1 (Plate I) is illustrated a rattler which will meet the requirements specified, and to which reference should be made.

Barrel. 17. The barrel of the machine shall consist of the heads, headliners, staves, and stave-liners conforming to the following requirements:

(*a*) *Heads.*—The heads may be cast in one piece with the trunnions which shall be $2\frac{7}{16}$ in. in diameter, and shall have a bearing 6 in. in length; or they may be cast with heavy hubs, which shall be bored out for $2\frac{7}{16}$ in. shafts and shall be key-seated for two keys, each $\frac{1}{2}$ by $\frac{3}{8}$ in. and spaced 90 deg. apart. The shaft shall be a snug fit and when keyed shall be entirely free from lost motion. The distance from the end of the shaft or trunnion to the inside face of the head shall be $15\frac{3}{8}$ in. in the head for the driving end of the rattler and $11\frac{3}{8}$ in. for the other head, and the distance from the face of the hubs to the inside face of the heads shall be $5\frac{1}{8}$ in.

The heads shall not be less than $\frac{3}{4}$ nor more than $\frac{7}{8}$ in. in thickness. In outline, each head shall be a regular 14-sided polygon

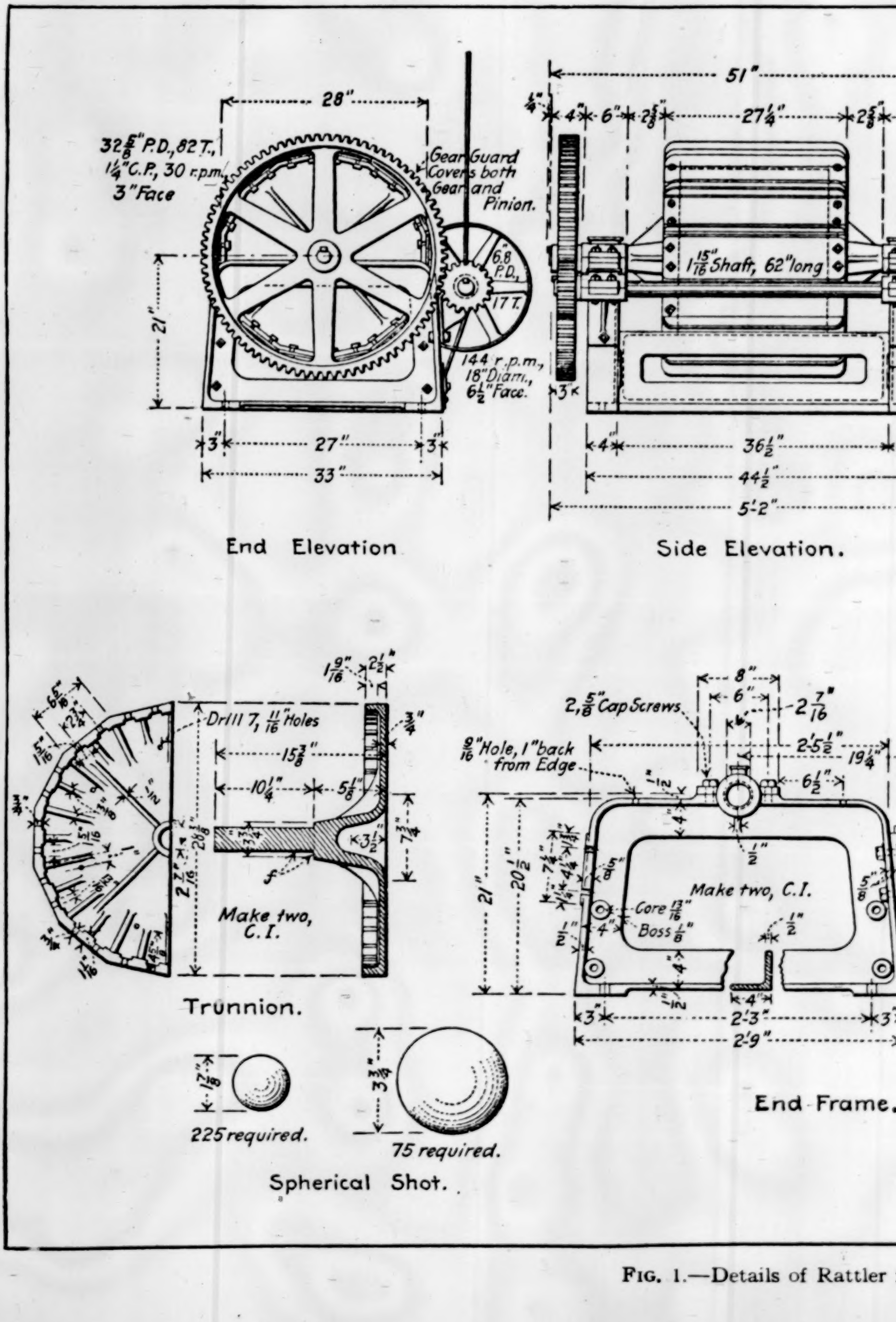
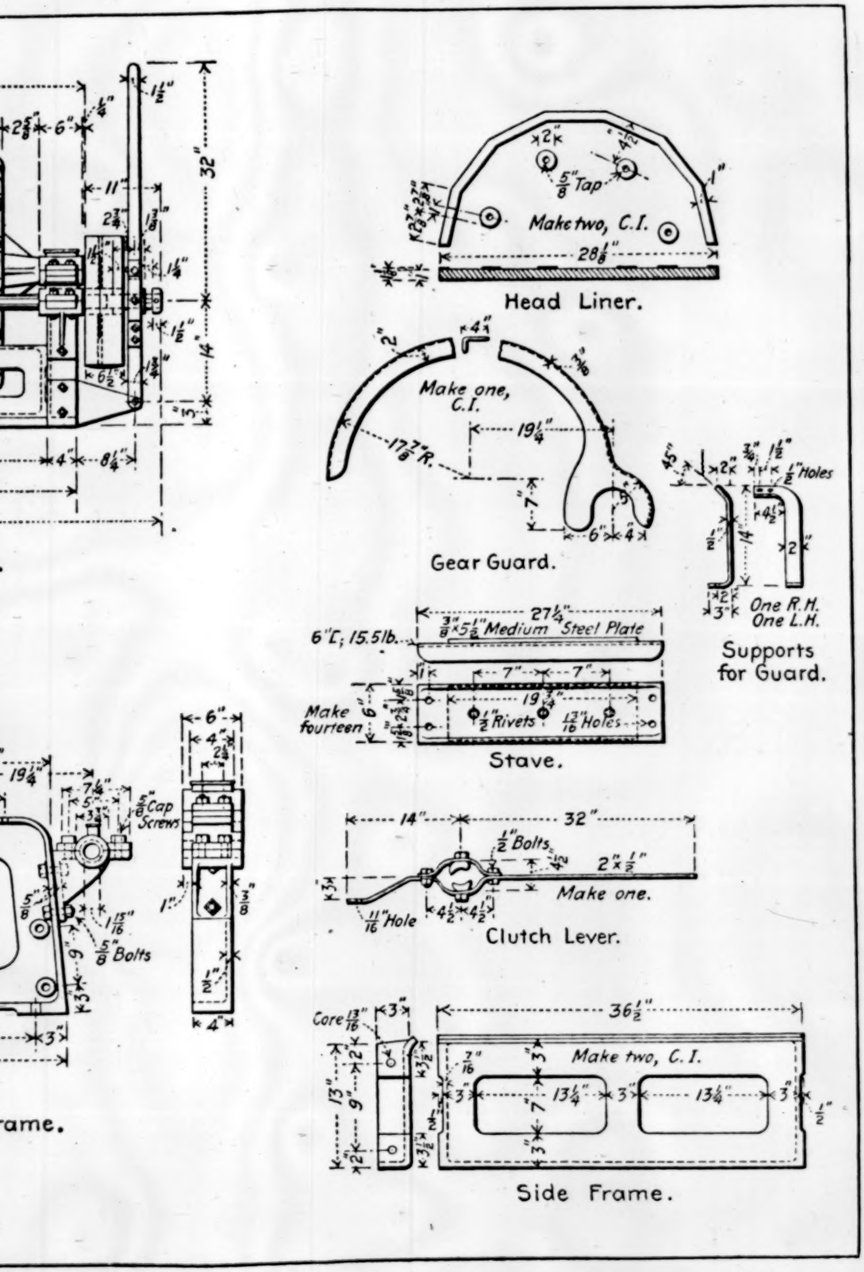

28"
32 5/8" P.D., 82 T., 1¼" C.P., 30 r.p.m., 3" Face
Gear Guard Covers both Gear and Pinion.
6.8" P.D., 17 T.
144 r.p.m., 18" Diam., 6½" Face.
21"
3"
27"
3"
33"
End Elevation
51"
¼"
4"
6"
2⅝"
27¼"
2⅝"
1 15/16" Shaft, 62" long
3"
4"
36½"
44½"
5'-2"
Side Elevation.
1 9/16"
2½"
6 5/8"
2 7/16"
1 5/16"
Drill 7, 11/16" Holes
3/4"
15⅞"
10¼"
5⅛"
3½"
7¾"
f
28½"
2 7/16"
Make two, C.I.
Trunnion.
2, 5/8" Cap Screws
8"
6"
2 7/16"
9/16" Hole, 1" back from Edge
2'-5½"
19¼"
6½"
½"
4"
21"
20½"
7¼"
4¼"
1¼"
5/8"
Make two, C.I.
Core 13/16"
Boss 1/8"
4"
2½"
4"
½"
4"
3"
2'-3"
3"
2'-9"
End Frame.
1⅞"
225 required.
3¾"
75 required.
Spherical Shot.

FIG. 1.—Details of Rattler

PLATE VII.
PROC. AM. SOC. TESTING MATS.
VOL. 28, PART I.
TENTATIVE SPECIFICATIONS FOR PAVING BRICK.


Head Liner.
Make two, C.I.
5/8" Tap
28 1/8"
Gear Guard.
Make one, C.I.
19 1/4"
17 7/8" R.
Supports for Guard.
1/2" Holes
One R.H.
One L.H.
6" [; 15.5 lb.
3/8"×5 1/2" Medium Steel Plate
27 1/4"
19 3/4"
1/2" Rivets
13/16" Holes
Make fourteen
Stave.
14"
32"
1/2" Bolts
2"×1/2"
Make one.
11/16" Hole
Clutch Lever.
Core 13/16"
36 1/2"
Make two, C.I.
13 1/4"
Side Frame.
5/8" Cap Screws
5/8" Bolts
rame.

attler for Testing Brick.

inscribed in a circle $28\frac{3}{8}$ in. in diameter. Each head shall be provided with flanges not less than $\frac{3}{4}$ in. in thickness and extending outward $2\frac{1}{2}$ in. from the inside face of the head to afford a means of fastening the staves. The surface of the flanges of the head shall be smooth and give a true and uniform bearing for the staves. To secure the desired true and uniform bearing, the surfaces of the flanges of the head shall be either ground or machined. The flanges shall be slotted on the outer edge, so as to provide for two $\frac{3}{4}$-in. bolts at each end of each stave, the slots to be $\frac{13}{16}$ in. in width and $2\frac{3}{4}$ in. center to center. Each slot shall be provided with a recess for the bolt head, which shall act to prevent the turning of the same. Between each two slots there shall be a brace $\frac{3}{8}$ in. in thickness extending down the outward side of the head not less than 2 in.

(*b*) *Headliners*.—There shall be for each head a cast-iron headliner, 1 in. in thickness and conforming to the outline of the head, but inscribed in a circle $28\frac{1}{8}$ in. in diameter. This headliner shall be fastened to the head by seven $\frac{5}{8}$-in. cap screws, through the head from the outside. Whenever these headliners become worn down $\frac{1}{2}$ in. below their initial surface level, at any point of their surface, they shall be replaced with new ones. The metal of these headliners shall be hard machinery iron and should contain not less than 1 per cent of combined carbon.

(*c*) *Staves*.—The staves shall be made of 6-in. medium-carbon steel structural channels $27\frac{1}{4}$ in. in length and weighing 15.5 lb. per lineal foot. The staves shall have two holes $\frac{13}{16}$ in. in diameter, drilled in each end, the center line of the holes being 1 in. from the end and $1\frac{3}{8}$ in. either way from the longitudinal center line. The spaces between the staves shall be as uniform as practicable, but shall not exceed $\frac{5}{16}$ in.

(*d*) *Staveliners*.—The interior or flat side of each stave shall be protected by a liner $\frac{3}{8}$ in. thick by $5\frac{1}{2}$ in. wide by $19\frac{3}{4}$ in. long. The liner shall consist of medium-carbon steel plate, and shall be riveted to the channel by three $\frac{1}{2}$-in. rivets, one of which shall be on the center line both ways and the other two on the longitudinal center line and spaced 7 in. from the center each way. The rivet holes shall be counter-sunk on the face of the liner and the rivets shall be driven hot and chipped off flush with the surface of the liners. These liners shall be inspected from time to time, and if found loose shall be at once re-riveted.

Preliminary Operation.

18. When a new rattler, in which a complete set of new staves is furnished, is first put into operation, it shall be charged with 400 lb. of shot of the same sizes, and in the same proportion as provided in

Section 22, and shall then be run for 18,000 revolutions at the rate of speed specified in Section 26(*a*). The shot shall then be removed and a standard shot charge inserted after which the rattler may be charged with brick for a test.

Relining. 19. No stave shall be used for more than 70 consecutive tests without renewing its lining. Two of the 14 staves shall be removed and relined at a time in such a way that of each pair, one falls upon one side of the barrel and the other upon the opposite side, and also so that the staves changed shall be consecutive, but not contiguous: for example, 1 and 8, 3 and 10, 5 and 12, 7 and 14, 2 and 9, 4 and 11, 6 and 13, etc., to the end that the interior of the barrel at all times shall present the same relative conditions of repair. The changes in the staves should be made at the time when the shot charges are being corrected, and the record must show the number of charges run since the last pair of new lined staves was placed in position.

The staves when bolted to the heads shall form a barrel 20 in. in length, inside measurement, between headliners. The liners of the staves shall be so placed as to drop between the headliners. The staves shall be bolted tightly to the heads by four $\frac{3}{4}$-in. bolts and each bolt shall be provided with a locknut and shall be inspected at not less frequent intervals than every fifth test and all nuts kept tight. A record shall be made after each inspection showing in what condition the bolts were found.

Barrel Frame. 20. The barrel shall be mounted on a cast-iron frame of sufficient strength and rigidity to support it without undue vibration. It shall rest on a rigid foundation with or without the interposition of wooden plates, and shall be fastened thereto by bolts at not less than four points.

Driving Mechanism. 21. The barrel shall be driven by gearing whose ratio of driver to driven is not less than one to four. The counter shaft upon which the driving pinion is mounted shall not be less than $1\frac{15}{16}$ in. in diameter, with bearing not less than 6 in. in length. If a belt drive is used, the pulley shall be not less than 18 in. in diameter and $6\frac{1}{2}$ in. in face. A belt at least 6 in. in width, properly adjusted, to avoid unnecessary slipping, should be used.

Abrasive Charge. 22. The abrasive charge shall consist of cast-iron spheres of two sizes.

(*a*) *Large Spheres.*—When new, the larger spheres shall be 3.75 in. in diameter and shall weigh approximately 7.5 lb. (3.40 kg.) each. Ten spheres of this size shall be used. These shall be weighed separately after each ten tests, and if the weight of any large sphere falls to 7 lb. (3.175 kg.) it shall be discarded and a new one substituted;

provided, however, that all of the large spheres shall not be discarded and substituted by new ones at any single time, and that in so far as possible the large spheres shall compose a graduated series in various stages of wear.

(*b*) *Small Spheres.*—When new, the smaller spheres shall be 1.875 in. in diameter and shall weigh approximately 0.95 lb. (0.43 kg.) each. In general, the number of small spheres in a charge shall not fall below 245 nor exceed 260. The collective weight of the large and small spheres shall be as nearly 300 lb. as possible. No small sphere shall be retained in use after it has been worn down so that it will pass a circular hole 1.75 in. in diameter, drilled in an iron plate $\frac{1}{4}$ in. in thickness, or weigh less than 0.75 lb. (0.34 kg.).

Further, the small spheres shall be tested by passing them over the plate mentioned or by weighing, after every ten tests, and any which pass through or fall below the specified weight, shall be replaced by new spheres, provided, further, that all of the small spheres shall not be rejected and replaced by new ones at any one time, and that so far as possible the small spheres shall compose a graduated series in various stages of wear. At any time that any sphere is found to be broken or defective it shall at once be replaced.

Chemical Composition of Charge.

23. The cast-iron abrasive spheres shall conform to the following requirements as to chemical composition:

Combined carbon	Not under	2.50	per cent
Graphitic carbon	" over	0.25	"
Silicon	" "	1.00	"
Manganese	" "	0.50	"
Phosphorus	" "	0.25	"
Sulfur	" "	0.08	"

For each new batch of spheres used, the chemical analysis shall be furnished by the maker or be obtained by the user, before introducing the spheres into the charge, and unless the analysis conforms to the requirements specified, the batch of spheres shall be rejected.

Scales.

24. The scales used shall be placed on a solid level foundation and shall be sufficiently sensitive to determine the initial weight of 10 bricks to the nearest 0.1 lb. The scale shall be tested by a standard test weight at intervals of not more than every ten tests.

TEST SPECIMEN

Test Specimen.

25. The number of brick per test shall be ten whole bricks for all weights of brick, and the brick shall be weighed to the nearest 0.1 lb. No brick should be selected as part of a regular test that would be rejected by any other requirements of the specifications under which the purchase is made.

PROCEDURE

Procedure. 26. (*a*) The sample, together with the abrasive charge shall be placed in the rattler and the rattler closed. The rattler shall be rotated at a uniform rate of not less than 29.5 nor more than 30.5 revolutions per minute, and 1800 revolutions shall constitute the test. A counting machine shall be attached to the rattler for counting the revolutions. A margin not to exceed ten revolutions will be allowed for starting and stopping. Only one start and stop per test is, in general, acceptable. If, from accidental causes, the rattler is stopped and started more than once during a test, and the percentage loss exceeds the maximum permissible under the specifications, the test shall be disqualified and another made.

(*b*) Any test, at the expiration of which a stave-liner is found detached from the stave or seriously out of position, shall be rejected.

Percentage Loss of Weight. 27. The loss shall be calculated as a percentage of the initial weight of the brick composing the charge, by weighing the brick remaining in the rattler at the end of the test, deducting this weight from the initial weight of the brick, dividing this difference by the original weight of the brick and multiplying by 100.

$$\text{Percentage of Loss} = \frac{\text{Original Weight} - \text{Weight after Testing}}{\text{Original Weight}} \times 100$$

In weighing the rattled brick, any piece weighing less than 1 lb. shall be rejected.

Corrected Percentage of Loss. 28. The percentages of loss, as calculated in accordance with Section 27, shall be corrected by subtracting from it the differential obtained from the following table, which corresponds to the initial weight of the ten brick composing the test charge. The corrected result shall be reported as the corrected percentage of loss.

WEIGHT OF 10 BRICK BEFORE TEST, LB.	CORRECTION DIFFERENTIAL, PER CENT
95 or over	0
90 to 94 inclusive	1.0
85 to 89 "	1.5
80 to 84 "	2.5
75 to 79 "	3.0
70 to 74 "	3.5
65 to 69 "	4.0
60 to 64 "	5.0
59 or under	6.0

In all cases where the initial weight of 10 brick in pounds and tenths of a pound lies between the upper limit of one grade and the lower limit of the next heavier grade, the brick shall be classified in the heavier grade when the fractional part of the weight is 0.5 lb. or more.

RECORD

Rattler Record.

29. A complete and continuous record shall be kept of the operation of all rattlers working under the Rattler Test. This record shall contain the following data concerning each test made:

1. The name of the person, firm or corporation furnishing each sample tested.
2. The name of the maker of the brick represented in each sample tested.
3. The name of the street or contract, which the sample represented.
4. The brands or marks upon the bricks by which they were identified.
5. The number of bricks furnished.
6. The date on which they were received for test.
7. The date on which they were tested.
8. The drying treatment given before testing, if any.
9. The length, width and thickness of the bricks.
10. The collective weight of the ten large spherical shot used in making the test at the time of their last standardization.
11. The number and collective weight of the small spherical shot used in making the test at the time of their last standardization.
12. The total weight of the shot charge, after its last standardization.
13. Certificate of the operator that he examined the condition of the machine as to staves, liners, and any other parts affecting the barrel, and found them to conform to the requirements at the beginning of the test.
14. Certificate of the operator of the number of charges tested since the last standardization of shot charge and last renewals of stave liners.
15. The time of the beginning and ending of each test, and the number of revolutions made by the barrel during the test, as shown by the counting machine.
16. Certificate of the operator as to number of stops and starts made in each test.
17. The initial collective weight of the ten brick composing the charge and their collective weight after rattling.
18. The loss calculated as a percentage of the initial weight and the calculation itself, the correction factor, and the corrected percentage of loss.
19. The number of broken bricks and remarks upon the portions which were included in the final weighing.
20. General remarks upon the test and any irregularities occuring in its execution.
21. The certificate of the operator that the test was made in accordance with the requirements of the American Society for Testing Materials and that the record is a true record.
22. The signature of the operator or person responsible for the test.
23. The location of the laboratory where the test was made and name of the owner.
24. The serial number of the test.

In the event of more than one copy of the record of any test being required, they may be furnished on separate sheets and marked duplicate, but the original record shall always be preserved intact and complete.

NOTE.—For the convenience of those making use of the test, the accompanying blank form, which provides space for the necessary data, is furnished and its use is recommended.

REPORT OF STANDARD RATTLER TEST OF PAVING BRICK

IDENTIFICATION DATA

Name of firm furnishing sample..........

Name of firm manufacturing sample..........

Street or job which sample represents..........

Brands or marks on the brick..........

Quantity furnished.......... Drying treatment..........

Date received.......... Date tested..........

Length.......... Width.......... Thickness..........

STANDARDIZATION DATA

WEIGHT OF CHARGE (After Standardization)	CONDITION OF LOCKNUTS ON STAVES	CONDITION OF SCALES	NUMBER AND POSITION OF FRESH STAVE LINERS	REPAIRS (Note any repairs affecting the condition of the barrel.)
10 Large spheres.......... Small spheres.......... Total..........				

Number of charges tested since last inspection..........

RUNNING DATA

TIME READINGS				REVOLUTION COUNTER READINGS	RUNNING NOTES, STOPS, ETC.
	HOURS	MINUTES	SECONDS		
Beginning of test.......... Final reading..........					

WEIGHTS AND CALCULATIONS

	PERCENTAGE LOSS (NOTE.—The calculation must appear.)
Initial weight of ten brick.......... Final weight of ten brick.......... Loss in weight.......... Percentage loss.......... Correction differential.......... Corrected percentage of loss..........	

Number of broken brick and remarks on same..........

I certify that the foregoing test was made in accordance with the methods of testing of the American Society for Testing Materials and is a true record.

Signature of Tester..........

Date..........

Location of Laboratory..........

Owner..........

Serial No..........

TENTATIVE METHODS OF TESTING BRICK[1]
(COMPRESSION, FLEXURE AND ABSORPTION)

Serial Designation: C 67 – 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1927; REVISED, 1928.

Scope. 1. These methods cover the following tests for brick:

The compression test;
The flexure or cross-bending test;
The absorption test.

COMPRESSION TEST

APPARATUS

Apparatus. 2. Any form of standard testing machine may be used for the compression test together with a spherical bearing block large enough entirely to cover the specimen.

TEST SPECIMEN

Test Specimen. 3. The test specimen shall consist of a half-brick. Any method which will produce a specimen with approximately plane and parallel ends, without shattering the specimen, may be used.

NOTE.—This permits the use of a suitable half-brick from the flexure test.

Preparation of Test Specimen. 4. A half-brick to be used for the compression test shall be prepared as follows: The two surfaces intended to receive the load from the testing machine shall receive a thin coating of shellac and be allowed to dry thoroughly. One of the shellaced bearing surfaces shall then receive a thin coat of a neat mortar of calcined gypsum (plaster of Paris). This mortared face of the specimen shall then be pressed on plate glass or a machined metal plate, previously oiled or covered with waxed paper, and the bedding material allowed to harden. This procedure shall be repeated with the other shellaced surface. Care shall be taken that the opposite faces so coated with bedding material shall be parallel. Depressions of recessed or panelled bricks shall be filled with neat portland-cement mortar which shall stand at least 24 hours before testing.

Number of Tests. 5. Compression tests shall be made on at least five half-brick test specimens from different bricks.

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[1] Criticisms of these Tentative Methods are solicited and should be directed to Mr. J. W. McBurney, Secretary of Committee C-3 on Brick, U. S. Bureau of Standards, Washington, D. C.

PROCEDURE

6. (*a*) The half-brick test specimen shall be tested, placed flat. **Procedure.**

(*b*) The bearing block shall be used on top of the test specimen in vertical testing machines. The center of the sphere of the bearing block shall be used in contact with the top bearing surface of the specimen, and in the vertical axis of the specimen. (Fig. 1.) The spherical bearing block shall be kept thoroughly lubricated to insure accurate adjustment, which should be made by hand under a small initial load.

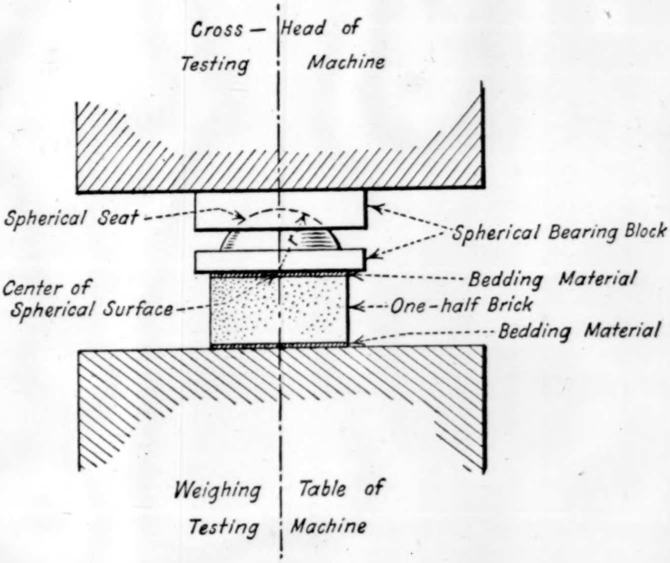
Cross – Head of
Testing Machine
Spherical Seat
Spherical Bearing Block
Bedding Material
Center of Spherical Surface
One-half Brick
Bedding Material
Weighing Table of
Testing Machine

FIG. 1.—Special Bearing Block for Use in Testing Brick.

(*c*) The speed of the moving head of the testing machine, during the application of the load, shall not be more than 0.05 in. per minute.

(*d*) During the test the beam of the testing machine shall be kept constantly in a floating position.

7. The compressive strength in pounds per square inch shall be reported as the total maximum load, W, in pounds, indicated by the testing machine, divided by the area, A, in square inches, of the minimum section of the specimen perpendicular to the line of application of the load. **Compressive Strength.**

The compressive strength in pounds per square inch shall be calculated from the formula:

$$\text{Compressive strength} = \frac{W}{A}$$

FLEXURE TEST

APPARATUS

Apparatus. 8. (*a*) Any form of standard testing machine with knife edges as described in Paragraph (*b*) may be used for the flexure test.

NOTE.—Portable apparatus properly calibrated may be used.

(*b*) Knife edges shall be straight and have full contact with the specimen or bearing plate and they shall have a length at least equal to the width of the brick to be tested. Their bases shall be so curved or rounded as to permit free movement of the working edges, both longitudinally and transversely. The use of knife edges of the type shown in Fig. 2 is recommended, although other types may be used which will provide free movement and at the same time insure full and even bearing at all times during the test.

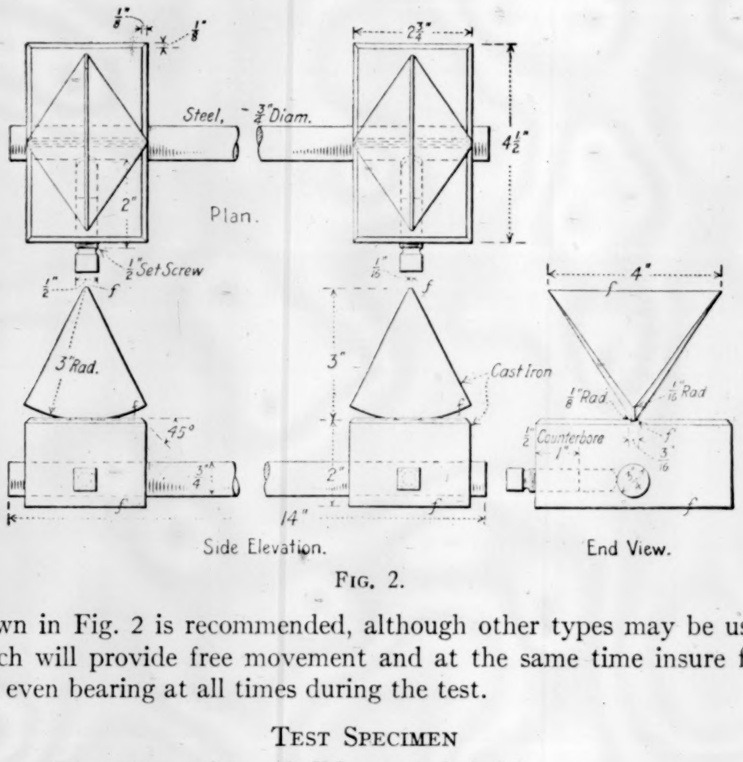

FIG. 2.

TEST SPECIMEN

Test Specimen. 9. The test specimen shall be a whole brick.

Number of Tests. 10. Flexure tests shall be made on at least five whole bricks.

PROCEDURE

Procedure 11. (*a*) A test specimen brick shall be placed flat-wise on the knife edges with a span of 7 in. and the load applied at mid-span.

(*b*) A steel bearing piece $\frac{1}{4}$ in. in thickness, $1\frac{1}{2}$ in. in width and of a length equal to the full width of the specimen shall be placed between the upper knife edge and the specimen.

(*c*) The speed of travel of the head of the testing machine, during the application of the load, shall not be more than 0.05 in. per minute.

Modulus of Rupture. 12. The modulus of rupture, R, in pounds per square inch shall be reported as calculated from the following formula:

$$R = \frac{3Wl}{2bd^2}$$

where W = the total load in pounds at which the brick failed;
l = the distance between the supports in inches;
b = the width of the brick in inches; and
d = the depth of the brick in inches.

ABSORPTION TEST

TEST SPECIMEN

Test Specimen. 13. The test specimen shall be a whole brick.

Number of Tests. 14. The absorption test shall be made on at least five whole bricks.

PROCEDURE

Procedure. 15. The sample shall be dried to constant weight at a temperature of 100 to 105° C. (212 to 221° F.).

16. When cool, the bricks shall be weighed separately on scales sensitive to within 0.5 per cent.

17. The dry bricks shall be totally immersed in soft, distilled or rain water at a temperature of 15.5 to 30.0° C. (60 to 86° F.) for five hours. The bricks shall then be removed, the surface water wiped off with a damp cloth and the bricks quickly weighed.

Calculation. 18. The percentage of absorption shall be calculated on the dry weight from the formula:

$$\text{Percentage of absorption} = \frac{100\,(b - a)}{a}$$

where a = weight of dry bricks; b = weight of saturated bricks.

TENTATIVE DEFINITIONS OF TERMS RELATING TO REFRACTORIES[1]

Serial Designation: C 71 - 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1927; REVISED, 1928.

Spalling.—Breaking or cracking of refractories to such an extent that fragments are separated, presenting newly exposed surfaces of the residual mass.

NOTE.—The causes of spalling may be classified under three main headings: namely, thermal, mechanical and structural, as follows:

Thermal:

(*a*) *Factors Related to Service.*—Rapidity and range of thermal fluctuation; contamination by slags and fluxes; tightness of joints; previous vitrification.

(*b*) *Factors Related to Refractories.*—Degree and uniformity of reversible thermal expansion; heat transfer; elasticity; plastic flow.

Mechanical:

(*a*) *Factors Related to Service.*—Rapid heating of wet brick; abuse in removing clinker and slag; unequal and excessive stresses; pinching; no provision for expansion; thin joints.

(*b*) *Factors Related to Refractories.*—Mechanical strength; toughness; accuracy of shape.

Structural:

(*a*) *Factors Related to Service.*—Slags and fluxes; character of the material in joints; insulation of refractories.

(*b*) *Factors Related to Refractories.*—Vitrification; shrinkage; nature of bond; structure; degree of burning.

Pyrometric Cone Equivalent (*P.C.E.*).—An index to the degree of fusion resulting in a cone of the material bending until the tip touches the plaque as a result of a definite heat treatment, in accordance with the Standard Method of Test for Softening Point of Fire-Clay Brick (Serial Designation: C 24) of the American Society for Testing Materials.[2]

NOTE.—The terms "fusion point," "softening point" "deformation point" and "melting point" have heretofore been loosely used for "pyrometric cone equivalent."

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[1] Criticisms of these Tentative Definitions are solicited and should be directed to Mr. L. J. Trostel, Secretary of Committee C-8 on Refractories, General Refractories Co. Laboratories, Box 935, Baltimore, Md.

[2] 1928 Supplement to Book of A.S.T.M. Standards, p. 89.

TENTATIVE SPECIFICATIONS AND TESTS

FOR

HOLLOW BURNED-CLAY FIREPROOFING, PARTITION AND FURRING TILE[1]

Serial Designation: C 56 – 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision

ISSUED, 1924; REVISED, 1926, 1927, 1928.

SPECIFICATIONS

Application.

1. These specifications apply to hollow fireproofing, partition and furring tile made from surface clay, shale, fire clay or admixtures thereof.

CLASSIFICATION

Classification.

2. (*a*) According to the results of the physical tests, tile shall be classified as Hard, Medium and Soft on the basis of the following strength and absorption requirements, the class of any lot being determined by the requirement which gives it the lowest rating:[2]

Class	Absorption, per cent			Compressive Strength Based on Net Area, lb. per sq. in.			
				End Construction		Side Construction	
	Mean of 5 Tests	Individual Maximum	Individual Minimum	Mean of 5 Tests	Individual Minimum	Mean of 5 Tests	Individual Minimum
Hard	6 to 12	15	5	4600 or more	3000	2400 or more	1700
Medium	12 to 16	19	5	3200 or more	2250	1600 or more	1100
Soft	16 to 25	25	5	2000 or more	1400	1200 or more	850

(*b*) Where end-construction tiles are used on the side they shall meet the requirements of that construction, and *vice versa.*

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[1] Criticisms of these Tentative Specifications and Tests are solicited and should be directed to Mr. H. D. Foster, Secretary of Committee C-10 on Hollow Masonry Building Units, Engineering Experiment Station, Ohio State University, Columbus, Ohio.

[2] As different types of clay are used in the manufacture of tile, color cannot be taken as indicative of classification.

WEIGHTS

Weights.

3. (*a*) The tile shall have the following dry weights determined as hereinafter specified:

STANDARD PARTITION TILE

DIMENSIONS, IN.	MINIMUM NUMBER OF CELLS	STANDARD WEIGHT, LB.
3 by 12 by 12	3	15
4 by 12 by 12	3	16
6 by 12 by 12	3	22
6 by 12 by 12	4	25
8 by 12 by 12	4	30
10 by 12 by 12	4	35
12 by 12 by 12	4	40

(*b*) A tolerance of 5 per cent will be allowed on the above standard weights.

DIMENSIONS

Dimensions.

4. No dimension shall vary more than 3 per cent from the standard dimensions for any form of tile.

FIRE RESISTANCE

Fire Resistance.

5. In cases where the fire resistance is an essential property the purchaser shall specify the degree of fire resistance (fire-resistance period) required, and the manufacturer shall supply such available information on the fire test performance of the given or closely similar product as will aid the purchaser in deciding whether the requirements are met. Further tests in accordance with the Tentative Specifications for Fire Tests of Building Construction and Materials (Serial Designation: C 19 – 26 T) of the American Society for Testing Materials[1] may be conducted by the purchaser.

WORKMANSHIP AND FINISH

Workmanship.

6. All tile shall be well burned, reasonably free from laminations and from such cracks, blisters, surface roughness and other defects as would evidently interfere with the proper setting of the tile or impair the permanence of the construction.

Scoring.

7. The exterior surface of all tile intended for plaster shall be scored in such a manner as to give good adhesion.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, p. 761 (1926); also 1928 Book of A.S.T.M. Tentative Standards, p. 292.

MARKING

8. All tile shall bear the initials, name or trademark of the manufacturer. Hollow tile intended for use in partitions shall also be marked "PARTITION." These marks shall be indented on the exterior of the tile and shall be plainly legible. **Marking.**

INSPECTION AND REJECTION

9. Proper facilities shall be provided the purchaser for sampling and inspection either at the factory or at the site of the work, as may be specified in the contract. At least 10 days from the time of sampling shall be allowed for the completion of the test. The inspection shall be based on the requirements specified above. All tests shall be made in accordance with the methods hereinafter prescribed. **Inspection.**

10. (*a*) Individual tile shall be rejected for failure to meet the weight, size, or workmanship and finish requirements. In case of failure to meet the absorption and strength requirements for the class specified, the seller may sort the shipment and new samples shall be selected by the purchaser from the retained lot and tested at the expense of the seller. In case the second set of samples fails to meet the test requirements, the entire lot shall be rejected. **Rejection.**

(*b*) By agreement, acceptance may be based on dry weight of the units, percentage of absorption, fire resistance and the workmanship and finish. **Acceptance.**

11. Except as specified in Section 10, and unless otherwise agreed, the expense of inspection and testing shall be borne by the purchaser. **Expense of Tests.**

TESTS

SAMPLING

12. Samples of tile for testing shall be selected by the purchaser or by a competent representative authorized by him to do this work. In all cases the samples shall be representative of the whole lot of tile from which they are selected. Full-size tile shall be taken in all cases. **Selection of Samples for Test.**

13. For the strength, absorption, and weight determinations, five individual tile shall be selected from each kiln or from each 100-ton lot. In no case shall less than five tile be taken. For the fire test the size of the test panel will govern the number of tile required. **Number of Samples.**

14. Samples for the strength and absorption tests shall be selected at the factory or at the site of the work, as specified in the contract. If the fire tests are to be made, it shall be so specified at the time of placing the order, samples being selected at the factory at least 45 days in advance of the time of filling the order. **Time and Place of Selecting Samples.**

Marking Samples. 15. All tile selected for test shall be plainly and permanently marked for reference by the testing operator.

WEIGHT DETERMINATIONS

Weight Determinations. 16. The five tile, if not in kiln-dry condition, shall be dried to constant weight at a temperature of not less than 100° C. (212° F.) and be weighed separately. The scale shall be sensitive to within 0.5 per cent of the weight of the smallest unit.

STRENGTH TESTS

Samples. 17. Five full-size dry tile shall be used.

Speed of Machine. 18. The speed of the moving head of the testing machine shall not be more than 0.05 in. per minute.

Bearing Block. 19. A spherical bearing block of proper design shall be placed on top of the test sample.

Capping. 20. (*a*) Bearing surfaces of the test samples and portions adjoining them which are liable to absorb water from the plastic capping shall be coated with shellac and allowed to dry. A quantity of plastic mortar made of a mixture of three parts (by volume) of portland cement and one part of unretarded gypsum (plaster of Paris) mixed with sufficient water to spread evenly shall be placed on a plain surface which has been coated with oil, and allowed to harden sufficiently to bear the weight of the tile. The surface to be capped shall be placed on this mortar, and while holding the specimen so that its axis is at right angles to the capping surface it shall be given a single firm pressure.

(*b*) The average thickness of the cap after the extruded plaster has been removed and the edges trued shall not be more than $\frac{1}{8}$ in. Patching of caps after setting shall not be permitted. Imperfect caps shall be removed and replaced with new ones.

(*c*) Where time is not available for aging the cement-gypsum cap, a cap of neat gypsum may be used, although the resulting tile strength will generally be lower than with the cement-gypsum cap. If the tile so capped fail to pass specification requirements on the score of strength, they shall be retested with portland-cement-gypsum caps aged not less than three days.

Time of Testing. 21. When the cement-gypsum cap is used it shall age at least three days before the tile is tested. Where the neat gypsum cap is used the tile may be tested as soon as the plaster has been well set, but not sooner than one hour after the sample has been capped.

Position of Tile. 22. All tile shall be tested in a position such that the load is applied in the same direction as in service.

ABSORPTION TESTS

23. The samples shall consist of five tile or three representative pieces from each of these five tile. If small pieces are used two shall be taken from the shell and one from an interior web, the weight of each piece to be not less than 227 g. (½ lb.). The samples shall have had their rough edges or loose particles ground off and be free from cracks from the failure of the tile in compression, where taken from tile which have been subjected to strength tests. **Selection of Test Samples.**

24. Each piece shall be marked so that it may be identified at any time with the tile from which it was taken. Markings which do not cover more than 5 per cent of the total superficial area of the piece shall be used. **Marking Test Samples.**

25. Preparatory to the absorption tests all samples shall be dried to constant weight in a drier or oven at a temperature of not less than 100° C. (212° F.). **Drying the Test Samples.**

26. The balance used shall be sensitive to within 0.2 per cent of the weight of the smallest unit or piece tested. **Accuracy of Weighings.**

27. After obtaining the dry weight of the samples they shall be immersed in soft, distilled or rain water, raised to the boiling point and boiled continuously for one hour, and then allowed to cool in water to room temperature. **Saturation of Samples.**

28. After saturation, the sample shall be removed from the water and allowed to drain for not more than one minute. The superficial water shall be removed with a damp cloth, after which they shall be weighed immediately. **Obtaining Saturated Weights.**

29. The test results shall be calculated as percentages of the initial dry weight, carried to the nearest first decimal place. The results shall be reported separately for each tile, with the average for the five tile. **Calculating and Reporting Results.**

TENTATIVE SPECIFICATIONS
FOR
BOILED LINSEED OIL[1]

Serial Designation: D 260 – 28 T

This is a Tentative Standard, published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1927; REVISED, 1928.

PROPERTIES AND TESTS

Properties. 1. Boiled linseed oil shall be pure linseed oil that has been treated by heating and incorporating compounds of lead, and at the option of the manufacturer suitable compounds of other drying metals, so as to produce a product that will dry rapidly. It shall be clear, free from sediment, and shall conform to the following requirements, when tested in accordance with the methods described in Sections 3 to 13 inclusive:

	MAXIMUM	MINIMUM
Time of drying on glass, hours	18.0	....
Specific Gravity, 15.5/15.5° C	0.945	0.931[a]
Acid number	7.5	....
Saponification Number	195.0	189.0
Unsaponifiable Matter, per cent	1.50	....
Iodine Number (Wijs)	....	170.0
Loss on Heating at 105 to 110° C., per cent	0.2	....
Ash, per cent	0.50	....
Lead, per cent	....	0.05

[a] When a high viscosity type of boiled linseed oil is required, the specific gravity shall not be less than 0.937.

METHODS OF TESTING

SOLUTIONS REQUIRED

Solutions Required. 2. The following reagents will be required:

(a) *Standard Sodium Hydroxide Solution.*—Prepare a stock concentrated solution of sodium hydroxide by dissolving NaOH in water in the proportion of 200 g. of NaOH to 200 cc. of water. Allow this solution to cool and settle in a stoppered bottle for several days. Decant the clear liquid from the precipitate of sodium carbonate into another clean bottle. Add clear barium hydroxide solution until no further precipitate forms. Again allow to settle until clear. Draw off about 175 cc. and dilute to 10 liters with freshly boiled distilled water. Preserve in a stock bottle provided with a large guard tube filled with soda lime. Determine the exact strength by titrating against pure benzoic acid (C_6H_5COOH) using phenolphthalein as indicator. (See U. S. Bureau of Standards *Scientific Paper No. 183.*) This solution will be approximately 0.25 *N*, but do not attempt to adjust it to any exact value. Determine its exact strength and make proper corrections in using it.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. R. L. Hallett, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 105 York St., Brooklyn, N. Y.

These tentative specifications are in effect a revision of the Standard Specifications for Purity of Boiled Linseed Oil from North American Seed (Serial Designation: D 11 – 15) and the Tentative Specifications for Purity of Boiled Linseed Oil from South American Seed (Serial Designation: D 78 – 21 T) which were accordingly discontinued in 1927.

(*b*) *Alcoholic Sodium Hydroxide Solution.*—Dissolve pure NaOH in 95-per-cent ethyl alcohol in the proportion of about 22 g. per 1000 cc. Let stand in a stoppered bottle. Decant the clear liquid into another bottle, and keep well stoppered. This solution should be colorless or only slightly yellow when used; it will keep colorless longer if the alcohol is previously treated with NaOH (about 80 g. to 1000 cc.), kept at about 50° C. for 15 days, and then distilled. For an alternate method see *Journal*, American Chemical Society, 1906, p. 395.

(*c*) *0.5 N Sulfuric Acid Solution.*—Add about 15 cc. of H_2SO_4 (sp. gr. 1.84) to distilled water, cool and dilute to 1000 cc. Determine the exact strength by titrating against freshly standardized NaOH or by any other accurate method. Either adjust to exactly 0.5 *N* strength or leave as originally made, applying appropriate correction.

(*d*) *Wijs Iodine Monochloride Solution.*—Dissolve iodine in glacial acetic acid that has a melting point of 14.7 to 15° C. and which is free from reducing impurities in the proportion so that 13 g. of iodine will be present in 1000 cc. of solution. The preparation of the iodine monochloride solution presents no great difficulty, but it shall be done with care and accuracy in order to obtain satisfactory results. There shall be in the solution no sensible excess either of iodine or more particularly of chlorine over that required to form the monochloride. This condition is most satisfactorily attained by dissolving in the whole of the acetic acid to be used the requisite quantity of iodine, using a gentle heat to assist the solution, if it is found necessary. The halogen content can be accurately measured by titration of a portion of the solution with 0.1 *N* sodium thiosulfate using the potassium iodide solution (15-per-cent) and the starch indicator as described in Section 9 in the method for the determination of the iodine number. Set aside a small portion of this solution while pure, and pass dry chlorine into the remainder until the halogen content of the solution is doubled. Ordinarily, it will be found that by passing the chlorine into the main part of the solution until the characteristic color of free iodine has just been discharged, there will be a slight excess of chlorine, which is corrected by the addition of the requisite amount of the unchlorinated portion until all free chlorine has been destroyed. A slight excess of iodine does little or no harm, but excess of chlorine must be avoided.

(*e*) *Starch Solution.*—Stir up 2 to 3 g. of potato starch or 5 g. of soluble starch with 100 cc. of 1-per-cent salicylic acid solution, add 300 to 400 cc. boiling water, and boil the mixture until the starch is practically dissolved. Dilute to 1 liter.

(*f*) *Potassium Iodide Solution* (*15-per-cent*).—Dissolve 150 g. of potassium iodide free from iodate in distilled water and dilute to 1000 cc.

(*g*) *Standard Sodium Thiosulfate Solution.*—Dissolve pure sodium thiosulfate in distilled water that has been well boiled to free it from carbon dioxide in the proportion so that 24.83 g. crystallized sodium thiosulfate will be present in 1000 cc. of the solution. It is best to let this solution stand for about two weeks before standardizing. Standardize with pure resublimed iodine. (See Treadwell-Hall, *Analytical Chemistry*, Vol. II, third edition, p. 646.) This solution will be approximately 0.1 *N* and it is best to leave it as it is after determining its exact iodine value, rather than to attempt to adjust it to exactly 0.1 *N* strength. Preserve in a stock bottle with a guard tube filled with soda lime.

METHODS

Methods of Testing.

3. *General.*—All tests shall be made on oil that has been thoroughly agitated before the removal of a sample for analysis.

Time of Drying on Glass.

4. In determining the time of drying on glass, flow the sample over a perfectly clean glass plate. Place the plate in a vertical position in air that is at 30° C. ± 2° C. and of a humidity of 32-per-cent ± 4 per cent saturation. After about two hours, test the film at intervals with the finger at points not less than 2.5 cm. from the edges. The film shall be considered dry when it no longer adheres to the finger and does not rub up appreciably when the finger is lightly rubbed across the surface.

Specific Gravity.

5. In determining specific gravity, use a pycnometer, accurately standardized and having a capacity of at least 25 cc., or any other

equally accurate method, making the test at 15.5° C. water being 1.000 at 15.5° C.

Acid Number.

6. In determining acid number, weigh from 5 to 10 g. of the sample. Transfer to a 300-cc. Erlenmeyer flask. Add 50 cc. of a mixture of equal parts by volume of 95-per-cent ethyl alcohol and c.p. reagent benzol. (This mixture should be previously titrated to a very faint pink with dilute alkali solution, using phenolphthalein as an indicator.) Add phenolphthalein indicator and titrate at once to a faint permanent pink color with 0.2 *N* sodium hydroxide solution. Calculate the acid number (milligrams KOH required for 1 g. of the oil).

Saponification Number.

7. In determining saponification number, weigh about 2 g. of the sample in a 300-cc. Erlenmeyer flask. Add 25 cc. of alcoholic sodium hydroxide or potassium hydroxide solution. Put a condenser loop inside the neck of the flask and heat on the steam bath for one hour. Cool, add phenolphthalein as indicator, and titrate with 0.5 *N* H_2SO_4. Run two blanks with the alcoholic sodium hydroxide solution. These should check within 0.1 cc. of 0.5 *N* H_2SO_4. From the difference between the number of cubic centimeters of 0.5 *N* H_2SO_4 required for the blank and for the determination, calculate the saponification number (milligrams KOH required for 1 g. of the oil).

Unsaponifiable Matter.

8. In determining unsaponifiable matter, weigh 8 to 10 g. of the sample. Transfer to a 250-cc. long-neck flask. Add 5 cc. of a strong solution of sodium hydroxide (equal weights of NaOH and H_2O) and 50 cc. of 95-per-cent ethyl alcohol. Put a condenser loop inside the neck of the flask and boil for two hours. Occasionally agitate the flask to break up the liquid, but do not project the liquid onto the sides of the flask. At the end of two hours, remove the condenser and allow the liquid to boil down to about 25 cc.

Transfer to a 500-cc. glass-stoppered separatory funnel, rinsing with water. Dilute with water to 250 cc., add 100 cc. of redistilled ether. Stopper and shake for one minute. Let stand until the two layers separate sharp and clear. Draw all but one or two drops of the aqueous layer into a second 500-cc. separatory funnel and repeat the process using 60 cc. of ether. After thorough separation, draw off the aqueous solution into a 400-cc. beaker, then the ether solution into the first separatory funnel, rinsing down with a little water. Return the aqueous solution to the second separatory funnel and shake out again with 60 cc. of ether in a similar manner, finally drawing the aqueous solution into the beaker and rinsing the ether into the first separatory funnel.

Shake the combined ether solution with the combined water rinsings and let the layers separate sharp and clear. Draw off the water and add it to the main aqueous solution. Shake the ether solution with two portions of water (about 25 cc. each). Add these to the main water solution.

Swirl the separatory funnel so as to bring the last drops of water down to the stop-cock and draw off until the ether solution just fills the bore of the stop-cock. Wipe out the stem of the separatory funnel with a bit of cotton on a wire. Draw the ether solution (portion-wise if necessary) into a 250-cc. flask and distill off. While still hot drain the flask into a small weighed beaker, rinsing with a little ether. Evaporate this ether, cool the beaker and weigh. (The unsaponifiable oil from adulterated drying oils may be volatile and as a consequence may evaporate on long heating. Therefore, heat the beaker on a warm plate, occasionally blowing out with a current of dry air. Discontinue heating as soon as the odor of ether is gone.)

Iodine Number.

9. In determining iodine number, place a small quantity of the sample in a small weighing burette or beaker. Weigh accurately. Transfer by dropping from 0.09 to 0.15 g. of oil to a 500-cc. bottle, having a well-ground glass stopper, or an Erlenmeyer flask, having a specially flanged neck for the iodine tests. Reweigh the burette or beaker and determine the amount of sample used. Add 10 cc. of chloroform. Whirl the bottle to dissolve the sample. Add 10 cc. of chloroform to each of two empty bottles like that used for the sample. Add to each bottle 25 cc. of the Wijs solution and let stand with occasional shaking for 1 hour in a dark place at a temperature of from 21 to 23° C. Add 10 cc. of the potassium iodide solution (15-per-cent) and 100 cc. of water. Titrate with 0.1 *N* sodium thiosulfate, using starch as an indicator. The titrations on the two blank tests should agree within 0.1 cc. From the difference between the average of the blank titrations and the titration on the sample and the iodine value of the thiosulfate solution calculate the iodine number of the sample tested. (Iodine number is given in centigrams of iodine to 1 g. of the oil.)

Loss on Heating at 105 to 110° C.

10. In determining the loss on heating, place 10 g. of the sample in an accurately weighed 50-cc. Erlenmeyer flask and weigh. Heat in an oven at a temperature between 105 and 110° C. for 30 minutes, then cool and weigh. Calculate the percentage loss. This determination shall be made in a current of carbon dioxide gas.

Ash.

11. In determining ash, weigh a porcelain crucible or dish. Add from 10 to 25 cc. of the sample, carefully weighing the amount added. Place on a stone slab on the floor of a hood. Ignite by playing the

flame of a burner on the surface of the oil and allow to burn quietly until most of the oil is burned off; then transfer to a muffle or over a flame and continue heating at a low temperature (not over a dull red) until all carbonaceous matter is consumed. Cool, weigh, and compute the percentage of ash.

Leads. 12. In determining lead, dissolve the ash in dilute nitric acid to which a little hydrogen peroxide has been added and determine lead by the sulfate or any other equally accurate method.

Appearance. 13. Transfer a portion of the sample to a clear glass tube and note appearance.

TENTATIVE SPECIFICATIONS
FOR
ALUMINUM POWDER FOR PAINTS
(ALUMINUM BRONZE POWDER)[1]

Serial Designation: D 266 - 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1927; REVISED, 1928.

Scope.

1. These specifications cover the material produced by a stamping process and commonly known as "aluminum bronze powder." The product produced by a spraying operation, which consists of more or less nearly spherical particles, and is sometimes known in the trade as "aluminum powder," is not covered by these specifications.

PROPERTIES AND TESTS

Properties and Tests.

2. (*a*) The aluminum powder shall be suitable for making aluminum paint. It shall match in luster and fineness a sample mutually agreed upon by the buyer and seller.

(*b*) It shall contain no filler or adulterant, such as mica, and shall be commercially pure aluminum in the form of fine, polished flakes with not to exceed 4 per cent of fatty or oily matter (polishing lubricant).

(*c*) A residue of not more than 0.2 per cent shall be retained on a No. 100 sieve, using alcohol as the wash liquid.

(*d*) The powder shall have good "leafing" properties. (By "leafing" is understood the property of forming an apparently continuous brilliant film over the entire free surface of a mixture of the powder in a suitable liquid, within one minute after cessation of stirring the mixture.) For this test the powder shall be mixed in the proportion of 2 lb. to a gallon of the liquid. As thus mixed it shall also give a free flowing, smooth, continuous coating.

NOTE.—A suitable liquid is made by mixing spar varnish conforming to the U. S. Government Master Specification for Water-Resisting Spar Varnish (Federal Specifications Board Specification No. 18b) with turpentine conforming to the Standard Specifications for Gum Spirits of Turpentine and Steam-Distilled Wood Turpentine (Serial Designation: D 13) of the American Society for Testing Materials[2] in such proportions that the mixture will have a viscosity of 0.65 to 0.85 poises (*B* to *C* of the Gardner-Holt scale).

Number of Tests.

3. One sample shall be taken at random from each lot of 1000 packages or fraction thereof for purpose of tests.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. R. L. Hallett, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 105 York St., Brooklyn, N. Y.

[2] 1927 Book of A.S.T.M. Standards, Part II, p. 236.

TENTATIVE SPECIFICATIONS

FOR

GOLD BRONZE POWDER[1]

Serial Designation: D 267 – 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1927; REVISED, 1928.

Scope. 1. These specifications cover the materials commonly known as gold bronze, pale gold bronze, and rich gold bronze powders.

PROPERTIES AND TESTS

Properties and Tests. 2. (*a*) The gold bronze powder shall be suitable for making gold bronze paint. It shall match in shade and fineness a sample mutually agreed upon by the buyer and seller.

(*b*) The powder shall be made from new ingot metals. It shall consist of fine polished flakes with not to exceed 3 per cent of fatty or oily matter (polishing lubricant) to give good "leafing" properties.

(*c*) A residue of not more than 0.2 per cent shall be retained on a No. 100 sieve, using alcohol as the wash liquid.

(*d*) The powder shall have good "leafing" properties. (By "leafing" is understood the property of forming an apparently continuous brilliant film over the entire free surface of a mixture of the powder in a suitable liquid, within one minute after cessation of stirring the mixture.) For this test the powder shall be mixed in the proportion of 3 to 4 lb. to a gallon of the liquid. As thus mixed it shall also give a free flowing, smooth, continuous coating.

NOTE.—A suitable liquid is made by mixing spar varnish conforming to the U. S. Government Master Specification for Water-Resisting Spar Varnish (Federal Specifications Board Specification No. 18b) with turpentine conforming to the Standard Specifications for Gum Spirits of Turpentine and Steam-Distilled Wood Turpentine (Serial Designation: D 13) of the American Society for Testing Materials[2] in such proportions that the mixture will have a viscosity of 0.65 to 0.85 poises (*B* to *C* of the Gardner-Holt scale).

Number of Tests. 3. One sample shall be taken at random from each lot of 1000 packages or fraction thereof for purpose of tests.

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[1] **Criticisms of these Tentative Specifications are solicited and should be directed to Mr. R. L. Hallett, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 105 York St., Brooklyn, N. Y.**

[2] 1927 Book of A.S.T.M. Standards, Part II, p. 236.

TENTATIVE SPECIFICATIONS
FOR
ALUMINUM POWDER FOR PAINTS
(ALUMINUM BRONZE POWDER)[1]

Serial Designation: D 266 – 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1927; REVISED, 1928.

Scope. 1. These specifications cover the material produced by a stamping process and commonly known as "aluminum bronze powder." The product produced by a spraying operation, which consists of more or less nearly spherical particles, and is sometimes known in the trade as "aluminum powder," is not covered by these specifications.

PROPERTIES AND TESTS

Properties and Tests. 2. (*a*) The aluminum powder shall be suitable for making aluminum paint. It shall match in luster and fineness a sample mutually agreed upon by the buyer and seller.

(*b*) It shall contain no filler or adulterant, such as mica, and shall be commercially pure aluminum in the form of fine, polished flakes with not to exceed 4 per cent of fatty or oily matter (polishing lubricant).

(*c*) A residue of not more than 0.2 per cent shall be retained on a No. 100 sieve, using alcohol as the wash liquid.

(*d*) The powder shall have good "leafing" properties. (By "leafing" is understood the property of forming an apparently continuous brilliant film over the entire free surface of a mixture of the powder in a suitable liquid, within one minute after cessation of stirring the mixture.) For this test the powder shall be mixed in the proportion of 2 lb. to a gallon of the liquid. As thus mixed it shall also give a free flowing, smooth, continuous coating.

NOTE.—A suitable liquid is made by mixing spar varnish conforming to the U. S. Government Master Specification for Water-Resisting Spar Varnish (Federal Specifications Board Specification No. 18b) with turpentine conforming to the Standard Specifications for Gum Spirits of Turpentine and Steam-Distilled Wood Turpentine (Serial Designation: D 13) of the American Society for Testing Materials[2] in such proportions that the mixture will have a viscosity of 0.65 to 0.85 poises (*B* to *C* of the Gardner-Holt scale).

Number of Tests. 3. One sample shall be taken at random from each lot of 1000 packages or fraction thereof for purpose of tests.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. R. L. Hallett, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 105 York St., Brooklyn, N. Y.

[2] 1927 Book of A.S.T.M. Standards, Part II, p. 236.

TENTATIVE SPECIFICATIONS
FOR
GOLD BRONZE POWDER[1]

Serial Designation: D 267 – 28 T

This is a Tentative Standard, published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1927; REVISED, 1928.

Scope. 1. These specifications cover the materials commonly known as gold bronze, pale gold bronze, and rich gold bronze powders.

PROPERTIES AND TESTS

Properties and Tests. 2. (*a*) The gold bronze powder shall be suitable for making gold bronze paint. It shall match in shade and fineness a sample mutually agreed upon by the buyer and seller.

(*b*) The powder shall be made from new ingot metals. It shall consist of fine polished flakes with not to exceed 3 per cent of fatty or oily matter (polishing lubricant) to give good "leafing" properties.

(*c*) A residue of not more than 0.2 per cent shall be retained on a No. 100 sieve, using alcohol as the wash liquid.

(*d*) The powder shall have good "leafing" properties. (By "leafing" is understood the property of forming an apparently continuous brilliant film over the entire free surface of a mixture of the powder in a suitable liquid, within one minute after cessation of stirring the mixture.) For this test the powder shall be mixed in the proportion of 3 to 4 lb. to a gallon of the liquid. As thus mixed it shall also give a free flowing, smooth, continuous coating.

NOTE.—A suitable liquid is made by mixing spar varnish conforming to the U. S. Government Master Specification for Water-Resisting Spar Varnish (Federal Specifications Board Specification No. 18b) with turpentine conforming to the Standard Specifications for Gum Spirits of Turpentine and Steam-Distilled Wood Turpentine (Serial Designation: D 13) of the American Society for Testing Materials[2] in such proportions that the mixture will have a viscosity of 0.65 to 0.85 poises (*B* to *C* of the Gardner-Holt scale).

Number of Tests. 3. One sample shall be taken at random from each lot of 1000 packages or fraction thereof for purpose of tests.

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[1] **Criticisms of these Tentative Specifications are solicited and should be directed to Mr. R. L. Hallett, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 105 York St., Brooklyn, N. Y.**

[2] 1927 Book of A.S.T.M. Standards, Part II, p. 236.

TENTATIVE SPECIFICATIONS
FOR
THE TOXIC INGREDIENTS IN ANTI-FOULING PAINTS[1]

Serial Designation: D 277 – 28 T

This is a Tentative Standard, published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1928.

Composition. 1. (*a*) Anti-fouling paints, when mixed ready to apply, shall contain both cuprous oxide and mercuric oxide in the following amounts:

	For General Service	In North Temperate Waters	In South Temperate Waters	In Tropical Waters
Cuprous Oxide, oz. per U. S. gal., not less than.........	14	25	20	14
Mercuric Oxide, oz. per U. S. gal., not less than.........	7	1⅓	5	14

(*b*) The amount of cuprous oxide material used in the manufacture of anti-fouling paints shall be in proportion to the cuprous oxide content, any cupric oxide present being considered as inert material.

CUPROUS OXIDE

Cuprous Oxide. 2. The cuprous oxide shall be a fine powder and shall conform to the following requirements:

Composition. (*a*) The cuprous oxide content shall not be less than 90 per cent when determined in accordance with the Tentative Method of Routine Analysis of Dry Cuprous Oxide (Serial Designation: D 283 – 28 T) of the American Society for Testing Materials.[2]

Fineness. (*b*) The total residue of coarse particles retained on a No. 325 sieve shall not be more than 2.5 per cent when determined in accordance with Method *A*. for Dry Pigments Practically Insoluble in Water as described in the Tentative Methods of Test for Coarse Particles in Dry Pigments and Coarse Particles and Skins in Mixtures of Pigments and Vehicles (Serial Designation: D 185 - 28 T) of the American Society for Testing Materials.[1]

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. R. L. Hallett, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 105 York St., Brooklyn, N. Y.

[2] See p. 910.

MERCURIC OXIDE

Mercuric Oxide. 3. The mercuric oxide shall be a finely powdered red or yellow mercuric oxide conforming to the following requirements:

Composition. (*a*) The mercuric oxide shall show on analysis not less than 91 per cent of mercury, which shall be in chemical combination, and shall show no free mercury when tested in accordance with the Tentative Method of Routine Analysis of Dry Mercuric Oxide (Serial Designation: D 284- 28 T) of the American Society for Testing Materials.[2]

Fineness. (*b*) The total residue of coarse particles retained on a No. 325 sieve shall not be more than 10 per cent when determined in accordance with Method *A*, Dry Pigments Practically Insoluble in Water in the Tentative Methods of Test for Coarse Particles in Dry Pigments and Coarse Particles and Skins in Mixtures of Pigments and Vehicles (Serial Designation: D 185 - 28 T) of the American Society for Testing Materials.[1]

Ash. (*c*) The ash residue shall not be more than 0.5 per cent when determined in accordance with the Tentative Method of Routine Analysis of Dry Mercuric Oxide (Serial Designation: D 284 - 28 T) of the American Society for Testing Materials.[2]

Impurities. (*d*) The mercuric oxide shall be practically free from acids and alkalies and from inert organic or inorganic fillers or adulterants.

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[1] See p. 874.

[2] See p. 912.

TENTATIVE METHODS OF TEST
FOR
COARSE PARTICLES IN DRY PIGMENTS AND COARSE PARTICLES AND SKINS IN MIXTURES OF PIGMENTS AND VEHICLES[1]

Serial Designation: D 185 - 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

Issued, 1928.

APPARATUS

Sieves. 1. The apparatus shall consist of a 3-in. No. 325 (44-micron) sieve conforming to the requirements of the Standard Specifications for Sieves for Testing Purposes (Serial Designation: E 11) of the American Society for Testing Materials.[2] A 3-in. No. 325 (44-micron) sieve for comparison purposes should be retained in the laboratory as a standard. Whenever a new sieve is secured, a practical test of its accuracy should be made by running on it and on the standard sieve a comparison test, using a pigment that has a considerable percentage of coarse particles. A reserve stock of such a pigment should be kept for this purpose.

PROCEDURE

A. Dry Pigments Practically Insoluble in Water.

(*1*) *For insoluble dry pigments, except metallic aluminum and bronze powders.*

Procedure. 2. The sieve shall be dried in an oven at from 105 to 110° C., cooled, and then weighed on an analytical balance, the weight being recorded to the nearest milligram.

3. The sample (25 g. for basic carbonate and basic sulfate white leads, 25 g. for red lead and mercuric oxide, 2 g. for black pigments of low specific gravity, 3 g. for Prussian blues and graphite, and 10 g.

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[1] Criticisms of these Tentative Methods are solicited and should be directed to Mr. R. L. Hallett, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 105 York St., Brooklyn, N. Y.

These methods, when adopted as standard, will supersede the present Standard Method of Test for Coarse Particles in Paint Pigments (Serial Designation: D 185 - 26), see 1927 Book of A.S.T.M. Standards, Part II, p. 286.

[2] 1927 Book of A.S.T.M. Standards, Part II, p. 917.

for all other pigments) of the pigment to be tested shall be weighed on an analytical balance to the nearest milligram. The sieve shall be wet on both sides with alcohol and the sample of pigment shall then be transferred to the sieve and wetted with alcohol.

4. The sieve shall then be held under a tap delivering about 300 to 500 cc. of the wash liquid (water) per minute. By slightly shaking the sieve, the pigment will be rapidly carried through. A soft camel's hair brush may be used in aiding the operation. If the sieve is held at a slight angle so that the pigment will gradually collect at one edge during the washing process, and then rotated, the pigment may be brushed out rapidly, with no risk of clogging the sieve. After the majority of the finely divided portion of the pigment has passed through the sieve (from 2 minutes to 1 hour, according to the kind of pigment), the sieve shall be placed in an 8-in. porcelain dish containing 250 cc. of the wash liquid (water). The sieve will thus be covered to a depth of about $\frac{1}{2}$ in. The pigment remaining on the sieve shall be brushed with a soft 1-in. camel's hair brush at the rate of two strokes per second during two periods of 10 seconds each. The sieve shall then be raised from the dish after each 10-second period to let the liquid on the sieve run through. The liquid in the dish should be changed after every two brushing periods. This operation shall be continued until the wash liquid (water) passing over the residue and through the sieve is clear and free from solid particles. When the washing appears to be complete, about 200 cc. of the wash liquid (water), after passing over the residue and through the sieve, shall be collected in a clean 400-cc. beaker. The liquid shall be stirred vigorously and the beaker set on a black surface in the case of white pigments and a white surface in the case of colored pigments. The washing shall not be considered complete until such a test fails to show any particles collected about the middle of the bottom of the beaker.

NOTE.—Occasionally, pigments will be found that foam when water is used as the wash liquid. In such instances, during the last washing in the porcelain dish the use of a liquid that breaks down the foaming and is readily miscible with water, such as alcohol, will usually overcome this difficulty.

5. When the washing is complete the pigment particles adhering to the brush shall be washed back onto the sieve and the water below the sieve wiped off. A few drops of alcohol and then of ether should be added to expedite drying. The sieve shall be dried for one hour, cooled, and weighed as described in Section 2. The percentage of coarse particles shall then be calculated.

(2) *For metallic aluminum and bronze powders.*

Procedure. 6. In the case of metallic aluminum and bronze powders the procedure described in Sections 2, 3, 4 and 5 shall be followed except that 5 g. of the material shall be used as a test sample and denatured alcohol, instead of water, shall be used as the wash liquid.

B. *Water-Soluble Pigments, Pastes in Oil, Pastes in Japan, Mixed Paints, and Enamels.*

Procedure. 7. The sieve shall be dried, cooled and weighed as described in Section 2. The sample to be tested shall contain 10 g. of pigment (25 g. of pigment with white leads and red lead). The weight shall be determined on an analytical balance to the nearest milligram and the sample transferred to a 250-cc. beaker. With dry pigments and pastes 100 cc. of kerosine shall be added to the beaker; with mixed paints and enamels 50 cc. of kerosine. The sieve shall then be wet on both sides with kerosine. The sample and the kerosine in the beaker shall be thoroughly mixed, breaking up all lumps, but not grinding, with the flattened end of a stirring rod. The contents of the beaker shall then be transferred to the sieve, using a wash bottle containing kerosine. Where small particles of pigment are retained on the stirring rod or walls of the beaker, they may easily be removed with a camel's hair brush.

8. The procedure described in Section 4 shall then be followed, using kerosine (siphoned from a vessel) instead of water as the wash liquid. The pigment particles adhering to the brush shall then be washed back onto the sieve and all kerosine shall be washed from the sieve with ether. The sieve shall be dried for one hour, cooled, and weighed, as described in Section 2. The percentage of coarse particles and skins (in the case of dry pigments, coarse particles) shall then be calculated.

C. *Ship-Bottom Paints Containing Resins and Alcohol.*

Procedure. 9. In the case of ship-bottom paints containing resins and alcohol the procedure described in Sections 7 and 8 shall be followed, except that a sample containing 10 g. of pigment shall be used and denatured alcohol, instead of water, shall be used as the wetting medium, for mixing with the paint, and as the wash liquid.

D. *Cellulose Ester Lacquers.*

Procedure. 10. In the case of cellulose ester lacquers the procedure described in Sections 7 and 8 shall be followed, except that a sample containing 10 g. of the material shall be used and a mixture of equal parts of ethyl acetate, benzol, and denatured alcohol, instead of water, shall be used as the wetting medium, for mixing with the lacquer and as the wash liquid.

TENTATIVE METHOD OF TEST
FOR
ALKALINITY OR ACIDITY OF PIGMENTS[1]

Serial Designation: D 278 - 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1928.

Procedure. 1. Shake a 20-g. sample of the dry pigment with 200 cc. of distilled water for 5 minutes, let settle, filter through a dry filter paper into a dry beaker, discarding the first 10 cc. of the filtrate. Transfer 100 cc. of the clear filtrate to a flask, add 3 drops of methyl orange solution (prepared by dissolving 1 g. of methyl orange in 1 liter of distilled water), and titrate to end point with 0.02 N H_2SO_4 solution if alkaline, or 0.02 N NaOH or Na_2CO_3 solution if acid.

Calculation. 2. Calculate alkalinity to milligrams of NaOH in 1 g. of the sample; calculate acidity to milligrams of NaOH required to neutralize 1 g. of the sample (1 cc. of 0.02 N solution is equivalent to 0.0008 g. NaOH).

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[1] Criticisms of this Tentative Method are solicited and should be directed to Mr. R. L. Hallett, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 105 York Street, Brooklyn, N. Y.

TENTATIVE METHODS OF TEST
FOR
BLEEDING OF PIGMENTS[1]

Serial Designation: D 279 - 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1928.

METHOD *A:* FOR DRY PIGMENTS TO BE USED IN CELLULOSE ESTER LACQUERS

Procedure. 1. Mix a suitable amount of the pigment to be tested with a minimum volume of dibutyl phthalate to give a thick paste when rubbed up with a sharp-edged steel spatula on a glass plate. Stir this paste into a clear cellulose ester lacquer and apply the paint evenly by brushing on a clean, smooth, dry metal panel. Apply the paint to only a part of the panel, leaving a margin of at least 2.5 cm. (1 in.) of unpainted metal around the painted portion. Allow the panel to dry for 30 minutes in a well-ventilated room at room temperature (70 to 90° F.). Flow successive coats of white lacquer over the entire surface of the panel until complete hiding is obtained, allowing the panel to dry for 20 minutes in a well-ventilated room at room temperature (70 to 90° F.) after applying each coat. Do not apply any white lacquer after the application of the particular coat that causes complete hiding. Let the completed panel dry for 24 hours and note the color of the two sections of the panel. If the color of the section containing the pigment under test does not match that of the adjoining area containing only the white lacquer, report the pigment as "bleeding."

METHOD *B:* FOR DRY PIGMENTS TO BE USED IN OIL OR OLEO-RESINOUS PAINTS AND ENAMELS:

Procedure. 2. Mix a suitable amount of the material to be tested with a minimum volume of a mixture of the following:

Raw linseed oil (Note 1)	5 parts by volume
Spar varnish (Note 2)	4 parts by volume
Liquid paint drier (Note 3)	1 part by volume

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[1] Criticisms of these Tentative Methods are solicited and should be directed to Mr. R. L. Hallett, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 105 York St., Brooklyn, N. Y.

NOTES

NOTE 1.—The raw linseed oil shall conform to the requirements of the Standard Specifications for Raw Linseed Oil (Serial Designation: D 234) of the American Society for Testing Materials.[1]

NOTE 2.—The spar varnish shall conform to the requirements of the U. S. Government Master Specification for Water-Resisting Spar Varnish (Federal Specifications Board Specification No. 18*b*).

NOTE 3.—The liquid paint drier shall conform to the requirements of the U. S. Government Master Specification for Liquid Paint Drier (Federal Specifications Board Specification No. 20*a*).

Rub up with a sharp-edged steel spatula on a glass plate to obtain a uniformly smooth, stiff paste. Thin with turpentine to give a paint of brushing consistency, and apply evenly by brushing on a clean, smooth, dry metal panel. Apply the paint to only a part of the panel, leaving a margin of at least 2.5 cm. (1 in.) of unpainted metal around the painted portion. Allow the panel to dry for 18 hours in a well-ventilated room at room temperature (70 to 90° F.). Brush a coat of Damar varnish (Damar resin cut in turpentine) over the entire surface of the panel. Report any color, other than that of the Damar varnish on the unpainted portion of the panel, as "bleeding."

METHOD *C:* FOR PASTES IN OIL

3. Mix a suitable amount of the paste to be tested with sufficient liquid paint drier (see Note 3 of Method *B*, above) to give a paint that will dry within 7 hours. Thin the mixture with turpentine to give a paint of brushing consistency. Thoroughly stir the paint, strain through a No. 100 sieve and apply by brushing to a clean, smooth, dry metal panel. Apply the paint to only a part of the panel, leaving a margin of at least 2.5 cm. (1 in.) of unpainted metal around the painted portion. Allow the panel to dry (should not require over 7 hours) in a well-ventilated room at room temperature (70 to 90° F.). After a total of 18 hours of drying under the above conditions, brush a coat of Damar varnish (Damar resin cut in turpentine) over the entire surface of the panel. Report any color, other than that of the Damar varnish on the unpainted portion of the panel, as "bleeding."

METHOD *D:* FOR PASTES IN JAPAN

4. Mix a suitable amount of the paste to be tested with turpentine to give a paint of brushing consistency. Add the turpentine slowly while thoroughly mixing with a sharp-edged steel spatula or paddle. Thoroughly stir this paint, strain through a No. 100 sieve and apply by brushing to a clean, smooth, dry metal panel. Apply

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[1] 1928 Supplement to Book of A.S.T.M. Standards, p. 99.

the paint to only a part of the panel, leaving a margin of at least 2.5 cm. (1 in.) of unpainted metal around the painted portion. Allow the panel to dry for 5 hours in a well-ventilated room at room temperature (70 to 90° F.). Brush a coat of Damar varnish (Damar resin cut in turpentine) over the entire surface of the panel. Report any color, other than that of the Damar varnish on the unpainted portion of the panel, as "bleeding."

TENTATIVE METHODS OF TEST
FOR
HYGROSCOPIC MOISTURE (AND OTHER MATTER VOLATILE UNDER THE TEST CONDITIONS) IN PIGMENTS[1]

Serial Designation: D 280 – 28 T

This is a Tentative Standard, published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1928.

METHOD *A:* FOR PIGMENTS THAT DO NOT DECOMPOSE AT 110° C.

APPARATUS

1. The apparatus shall consist of the following:

Apparatus. (*a*) A wide-mouth cylindrical glass weighing bottle (flat form; about 30 mm. in height, and about 70 mm. in diameter), provided with a ground-in glass stopper. Or, an aluminum moisture dish (about 90 mm. in diameter and about 50 mm. in depth) with a tightly-fitting cover.

(*b*) An oven in which a temperature of from 105 to 110° C. can be maintained.

(*c*) An analytical balance.

PROCEDURE

2. The procedure shall be carried out as follows:

Procedure. Weigh accurately the glass weighing bottle and stopper or the aluminum moisture dish with cover. Place a sample of from 3 to 5 g. of the pigment in the clean, dry weighing bottle or in the clean, dry aluminum moisture dish. Insert the stopper (or cover) and weigh. Subtract the weight of the vessel from the total weight to obtain the weight of sample used in the test. Remove the stopper (or cover) and place it and the bottle (or dish) containing the sample in an oven that has been previously heated to from 105 to 110° C.; heat for 2 hours at a temperature of from 105 to 110° C. Replace the stopper (or cover), cool in a desiccator and weigh. Calculate the total loss in weight to percentage of moisture and other volatile matter.

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[1] **Criticisms of these Tentative Methods are solicited and should be directed to Mr. R. L. Hallett, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 105 York St., Brooklyn, N. Y.**

METHOD *B:* FOR PIGMENTS THAT DECOMPOSE AT 110° C.

APPARATUS

Apparatus. 3. The apparatus shall consist of the following:

(*a*) A glass weighing bottle as described in Section 1 (*a*).

(*b*) An open-tube manometer made of glass tubing 6 mm. in diameter, filled with mercury to approximately 86 cm., fitted with rubber pressure-tubing attached to a T-joint leading to the desiccator and the pump.

NOTE.—The difference in levels of the mercury in the manometer when the system is in operation, subtracted from the barometer reading taken at the same time, gives the vacuum of the system in millimeters of mercury. The difference between the barometer and the manometer reading should not exceed 3 mm.

(*c*) A glass desiccator, having a hole at the side or in the cover, constructed with heavy walls to withstand a vacuum of one atmosphere. The hole at the side is closed with a one-hole rubber stopper carrying a glass tube with rubber tube connection and a pinch-cock or with a glass stop-cock ground to fit the tubulature.

(*d*) An oil vacuum pump with a motor to give a vacuum of not more than 3 mm.

NOTE.—The "Hyvac" oil pump is satisfactory.

(*e*) An analytical balance.

PROCEDURE

Procedure. 4. The procedure shall be carried out as follows:

Weigh accurately the glass weighing bottle and stopper. Place a sample of from 1 to 3 g. of the pigment in the clean, dry weighing bottle, insert the stopper and weigh. Subtract the weight of the vessel from the total weight to obtain the weight of sample used in the test. Remove the stopper and place it and the bottle containing the sample in the desiccator containing *fresh,* magnesium perchlorate trihydrate.[1] Close the desiccator, attach to the pump and *gradually* evacuate until the manometer indicates that the vacuum, which should not be greater than 3 mm., is constant. Close the pinch-cock or stop-cock, stop the pump, and let stand at room temperature (70 to 90° F.) for 24 hours. Admit air slowly to the desiccator by means of the pinch-cock or stop-cock, remove the cover, replace the stopper in the weighing bottle and weigh. Repeat the evacuations and weighings until the loss in weight does not exceed 0.5 mg. in 24 hours. Calculate the total loss in weight to percentage of moisture and other volatile matter.

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[1] H. H. Willard and G. Frederick Smith, "The Preparation and Properties of Magnesium Perchlorate and Its Use as a Drying Agent," *Journal,* Am. Chemical Soc., Vol. 44, pp. 2255–59 (1922). The compound is sold under the trade name "Dehydrite."

NOTE.—Caution should be used in evacuating glass desiccators. The vacuum should be applied gradually. Desiccators will maintain a vacuum for a greater length of time when a thin film of a suitable stop-cock lubricant[1] is applied to the ground surfaces. Desiccators when evacuated for the first time should be wrapped in towels or covered by other means to prevent possible injury to the operator.

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[1] Martin Shepherd and P. G. Ledig, "Rubber Stop-cock Lubricants for High Vacuum and Other Uses," *Industrial and Engineering Chemistry*, Vol. 19, p. 1059 (1927).

TENTATIVE METHOD OF TEST
FOR
OIL ABSORPTION OF PIGMENTS[1]

Serial Designation: D 281 – 28 T

This is a Tentative Standard, published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1928.

Procedure. 1. Weigh exactly 1 g., or any multiple thereof, of the thoroughly mixed and air-dried pigment, and place upon a glass plate or marble slab. Weigh accurately a dropping bottle (Note 1) fitted with a ground-in pipette and rubber bulb and containing some clear, well-settled, raw linseed oil (free from foots) and having an acid value (Note 2) of from 1 to 3 (Note 3). Add the linseed oil gradually, drop-by-drop (by means of the pipette) to the pigment, and after the addition of each drop thoroughly incorporate the oil with the pigment by rubbing up with a sharp-edged steel spatula. The test is complete when exactly enough oil has been incorporated with the pigment to produce a very stiff, putty-like paste, which does not break or separate. Accurately weigh the bottle and oil (Note 1) and determine by difference the weight of oil used.

NOTES

NOTE 1.—Instead of weighing the linseed oil in the dropping bottle, it may be added dropwise from an accurate burette. The number of cubic centimeters of linseed oil used is then multiplied by the specific gravity of the oil in order to obtain the corresponding weight of the oil in grams.

NOTE 2.—Care should be taken that the linseed oil used in comparative or simultaneous tests has the same acid value.

NOTE 3.—While raw linseed oil is specified, other liquids (such as refined oil) may be used by mutual agreement.

Calculation. 2. From the weights of oil and pigment used in the test, calculate the number of pounds of oil required to exactly "wet" 100 lb. of pigment.

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[1] Criticisms of this Tentative Method are solicited and should be directed to Mr. R. L. Hallett, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 105 York St., Brooklyn, N. Y.

TENTATIVE METHODS OF TEST
FOR
MASS COLOR AND TINTING STRENGTH OF PIGMENTS[1]

Serial Designation: D 282 - 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1928.

MASS COLOR

Mass Color.

1. Weigh a 1-g. sample of the pigment under test and rub up to a smooth uniform paste with linseed oil on a glass plate or stone slab. Rubbing up (mixing with oil) is best done with a muller and should be continued until no lumps remain. Treat a 1-g. sample of the mutually agreed upon standard pigment in exactly the same manner using an equal amount of the same linseed oil and the same amount of rubbing. Spread the two pastes side by side on a clear, colorless strip of glass and compare the mass colors as shown on both sides of the glass. A pigment shall be considered as passing this test when its mass color is the same as that of the mutually agreed upon standard.

TINTING STRENGTH[2]

SAMPLES

Test Samples.

2. The quantity of pigment necessary for the determination of the tinting strength[2] varies according to the value of the tinting strength, and the amount of linseed oil required is influenced by the oil absorption of the pigment. The following quantities of pigment, linseed oil and pure zinc oxide will generally be sufficient for the test:

(*a*) *Red and brown pigments containing iron and manganese* (red and brown iron oxides, umbers, siennas).—Use 0.02 g. of pigment, 0.7 cc. of linseed oil, and 1 g. of pure ZnO.

(*b*) *Ochers.*—Use 0.05 g. of pigment, 0.7 cc. of linseed oil, and 1 g. of pure ZnO.

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[1] Criticisms of these Tentative Methods are solicited and should be directed to Mr. R. L. Hallett, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 105 York St., Brooklyn, N. Y.

[2] Holley, "Analysis of Paint and Varnish Products," p. 126 (1912).

(*c*) *Yellow and orange pigments containing chromium compounds.*—Use 0.02 g. of pigment, 1.4 cc. of linseed oil and 2 g. of pure ZnO.

(*d*) *Iron cyanide blue pigments* (Prussian blue, etc.).—Use 0.01 g. of pigment, 2.1 cc. of linseed oil and 3 g. of pure ZnO.

(*e*) *Ultramarine blues.*—Use 0.01 g. of pigment, 0.7 cc. of linseed oil and 1 g. of pure ZnO.

(*f*) *C. P. Chrome greens.*—Use 0.01 g. of pigment, 1.4 cc. of linseed oil and 2 g. of pure ZnO.

(*g*) *Extended or commercial chrome greens.*—Use 0.05 g. of pigment, 0.7 cc. of linseed oil and 1 g. of pure ZnO.

(*h*) *Black pigments.*—Use 0.01 g. of pigment, 7.0 cc. of linseed oil and 10.0 g. of pure ZnO.

(*i*) *White pigments*[1] (white leads, zinc oxide, lithopone, titanium-barium and titanium-calcium pigments).—Use 10 g. of pigment in each case; 7.0 cc. of linseed oil for zinc oxide, 6.0 cc. for lithopone, titanium-barium and titanium-calcium pigments, and 2.0 cc. for white leads, and in place of the usual addition of pure zinc oxide use 0.01 g. of lampblack in each case.

PROCEDURE

Procedure.

3. Weigh accurately a sample (see Section 2) of the pigment to be tested. Place the pigment on a sheet of plate glass approximately 13 by 15 by $\frac{3}{4}$ in. with its face lightly ground (No. 303 optical emery). Add a quantity (see Section 2) of clear, well-settled, raw linseed oil (free from foots) (Note 1) to the pigment, using a burette which delivers 37 drops of oil per cubic centimeter. Rub up with a clean, sharp-edged steel spatula until the mass appears to be homogeneous. Add the quantity of pure zinc oxide (see Section 2), and grind with a circular motion 50 times, using a circular glass muller approximately $2\frac{1}{2}$ in. in thickness with a face about 3 in. in diameter, lightly ground (No. 303 optical emery). Gather-up with the steel spatula and grind out twice more in like manner, giving the muller a uniform pressure.

Weigh a similar amount of a carefully selected and mutually agreed upon standard pigment and treat in exactly the same manner as the pigment under test, using the same amounts of linseed oil and pure zinc oxide (Note 2).

Transfer portions of each paste to a microscope slide, quite close together, and then draw a palette knife across both samples so as to make them meet in a line. Any differences in tint are then easily seen. Compare the tints as shown on both sides of the glass.

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[1] In the case of white pigments this test is often referred to as "color strength."

NOTE 1.—The use of "oxidized" oil (oil that has become "fatty" by standing in a can or bottle) should be avoided. Poppy oil could be used but it is quite as necessary to have it reasonably fresh as when linseed oil is used. In either case "stringy" pastes are not reliable.

NOTE 2.—In some cases it may be necessary to mix the standard pigment and the pigment under test to the same apparent consistency.

CALCULATION

Calculation.

4. If it is desired to express quantitatively the tinting strength of the pigment, consider the weight of the mutually agreed upon standard pigment (equivalent to the weight of the pigment under test, see Section 2) as having a tinting strength of 100. Prepare a paste of the standard pigment in accordance with Section 3 by varying the amount of the standard until the tinting strength equals that of the pigment under test. The tinting strength is equivalent to 100 multiplied by the ratio of the latter to the former weight of the standard pigment.

For example, consider the test of an iron oxide. The weight of the standard pigment (equivalent to the weight of the iron oxide sample, see Section 2) for a tinting strength of 100 is 0.02 g. ($=A$). Vary this quantity in units of 5 per cent (0.019 or 0.021 g.) until the amount required to match the tinting strength of the iron oxide is determined, call this weight B, then:

$$\text{Tinting strength} = \frac{B}{A} \times 100$$

NOTE.—If the tone varies it will be difficult to make this measurement. Tinting strengths, as inferred from depths of tint visually compared, vary with the concentrations used in the pigment mixtures. In this way relative strengths may even be actually reversed. Thus, of two pigments, the strength of one may seem the greater at one dilution but the lesser at another dilution.

TENTATIVE METHODS OF ROUTINE ANALYSIS
OF
WHITE LINSEED OIL PAINTS[1]

Serial Designation: D 215 - 28 T

This is a Tentative Standard, published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1925; REVISED, 1927, 1928.

PRELIMINARY PROCEDURE

On receipt of a sample make a record of the label, noting especially the brand, the name of the manufacturer, and any statement as to composition and net contents. Weigh the unbroken package, open, note odor and condition of the contents, pour into a clean container, and mix thoroughly by pouring from one container to the other, finally leaving the well-mixed sample in the second container, which shall be tightly closed. The well-mixed sample is used at once for the determinations described under "Methods." The original can and cover may be cleaned with gasoline, wiped dry, and then weighed. This weight subtracted from the original weight will give the net weight of the contents. If desired, the specific gravity of the paint may be determined and the weight per gallon calculated, and the volume of paint and the capacity of the container may be measured.

REAGENTS REQUIRED

Extraction Mixture.—10 volumes ether (ethyl ether);
6 volumes benzol;
4 volumes methyl alcohol;
1 volume acetone.

Aqueous Sodium Hydroxide.—Dissolve 100 g. of NaOH in distilled water and dilute to 300 cc.

Alcoholic Sodium Hydroxide Solution.—Dissolve pure NaOH in 95-per-cent ethyl alcohol in the proportion of about 22 g. per 1000 cc. Let stand in a stoppered bottle. Decant the clear liquid into another bottle and keep well stoppered. This solution should be colorless or only slightly yellow when used, and it will keep colorless longer if the alcohol is previously treated with sodium hydroxide (about 80 g. to 1000 cc.), kept at about 50° C. for 15 days, and then distilled.

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[1] Criticisms of these Tentative Methods are solicited and should be directed to Mr. R. L. Hallett, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 105 York St., Brooklyn, N. Y.

Wijs Solution.—Dissolve iodine in glacial acetic acid that has a melting point of 14.7 to 15° C. and is free from reducing impurities in the proportion so that 13 g. of iodine will be present in 1000 cc. of solution. The preparation of the iodine monochloride solution presents no great difficulty but it shall be done with care and accuracy in order to obtain satisfactory results. There shall be in the solution no sensible excess either of iodine or more particularly of chlorine over that required to form the monochloride. This condition is most satisfactorily attained by dissolving in the whole of the acetic acid to be used the requisite quantity of iodine, using a gentle heat to assist the solution, if it is found necessary. Set aside a small portion of this solution while pure, and pass dry chlorine into the remainder until the halogen content of the solution is doubled. Ordinarily, it will be found that by passing the chlorine into the main part of the solution until the characteristic color of free iodine has just been discharged, there will be a slight excess of chlorine which is corrected by the addition of the requisite amount of the unchlorinated portion until all free chlorine has been destroyed. A slight excess of iodine does little or no harm, but excess of chlorine must be avoided.

Standard Sodium Thiosulfate Solution.—Dissolve pure sodium thiosulfate in distilled water (that has been well boiled to free it from carbon dioxide) in the proportion of 24.83 g. crystallized sodium thiosulfate to 1000 cc. of the solution. It is best to let this solution stand for about two weeks before standardizing. Standardize with pure resublimed iodine, pure potassium bi-iodate, or pure KIO_3 (see Treadwell-Hall, Analytical Chemistry, Vol. 2.) This solution will be approximately 0.1 *N*, and it is best to leave it as it is after determining its exact iodine value, rather than to attempt to adjust it to exactly 0.1 *N*. Preserve in a stock bottle provided with a guard tube filled with soda lime.

Starch Solution.—Stir up 2 to 3 g. of potato starch or 5 g. of soluble starch with 100 cc. of 1-per-cent salicylic acid solution, add 300 to 400 cc. of boiling water, and boil the mixture until the starch is practically dissolved, then dilute to 1 liter.

Potassium Iodide Solution.—Dissolve 150 g. of potassium iodide free from iodate in distilled water and dilute to 1000 cc.

Acid Ammonium Acetate Solution.—Mix 150 cc. of 80-per-cent acetic acid, 100 cc. of water, and 95 cc. of strong ammonia (sp. gr. 0.90).

Ammonium Polysulfide.—Pass H_2S gas into 200 cc. of strong ammonium hydroxide (sp. gr. 0.90) in a bottle immersed in running water or in iced water until the gas is no longer absorbed; then add 200 cc. of strong ammonium hydroxide (sp. gr. 0.90) and dilute with water to 1000 cc. Digest this solution with 25 g. of flowers of sulfur for several hours and filter.

"Lead Acid."—Mix 300 cc. of H_2SO_4 (sp. gr. 1.84) and 1800 cc. of distilled water. Dissolve 1 g. of c. p. lead acetate in 300 cc. of distilled water and add this to the hot solution, stirring meanwhile. Let stand at least 24 hours and siphon through a thick asbestos filter.

Potassium Permanganate Solution.—Dissolve 3.2 g. of pure potassium permanganate in a liter of distilled water, let stand 8 to 14 days, siphon off the clear solution (or filter through an asbestos filter), and standardize as follows: In a 400-cc. beaker dissolve 0.25 to 0.30 g. (accurately weighed) of Bureau of Standards' sodium oxalate in 250 cc. of hot water (80 to 90° C.) and add 15 cc. of dilute sulfuric acid (1:1). Titrate at once with the potassium permanganate solution, stirring the liquid vigorously and continuously. The permanganate must not be added more rapidly than 10 to 15 cc. per minute, and the last 0.5 to 1 cc. must be added dropwise with particular care to allow each drop to be fully decolorized before the next is introduced. The temperature of the solution should not be below 60° C. by the time the end point is reached. (Too rapid cooling may be prevented by allowing the beaker to stand on a small asbestos-covered hot plate during the titration. The use of a small thermometer as a stirring rod is most convenient.) The weight of sodium oxalate used multiplied by 0.833 gives its iron equivalent. The permanganate solution should be kept in a glass stoppered bottle painted black to keep out light.

The iron (Fe) value of the $KMnO_4$ multiplied by 1.076 theoretically equals its antimony (Sb) equivalent. However, for use in determining antimony, the $KMnO_4$ is best standardized as follows: To 0.25 g. of pure metallic antimony in a 500-cc. Pyrex Erlenmeyer flask, add 12 to 15 cc. of concentrated H_2SO_4 and 10 to 12 g. of K_2SO_4; heat until all the antimony is dissolved, cool, dilute to 250 cc. with water, add 20 cc. of concentrated HCl, cool to 10 to 15° C., and titrate with the $KMnO_4$ solution until a faint pink color is obtained. For special work, after digesting, dilute to 100 cc. with water, add 1 to 2 g. of Na_2SO_3, and boil until all the SO_2 is expelled. This is shown when no blue color is obtained with starch-iodate paper (see below); the volume will be reduced about one-half. Dilute to 250 cc. with water, add 20 cc. of HCl (sp. gr. 1.19), and complete as described.

Standard Potassium Ferrocyanide.—Dissolve 22 g. of the pure salt in water and dilute to 1000 cc. To standardize, transfer about 0.2 g. (accurately weighed) of pure metallic zinc or freshly ignited pure zinc oxide to a 400-cc. beaker. Dissolve in 10 cc. of HCl and 20 cc. of water. Drop in a small piece of litmus paper, add ammonium hydroxide until slightly alkaline, then add HCl until just acid, and then 3 cc. of strong HCl. Dilute to about 250 cc. with hot water and heat nearly to boiling. Run in the ferrocyanide solution slowly from a burette with constant stirring until a drop tested on a white porcelain plate with a drop of the uranyl indicator shows a brown tinge after standing one minute. A blank should be run with the same amounts of reagents and water as in the standardization. The amount of ferrocyanide solution required for the blank should be subtracted from the amounts used in standardization and in titration of the sample. The standardization must be made under the same conditions of temperature, volume, and acidity as obtained when the sample is titrated.

Uranyl Indicator for Zinc Titration.—A 5-per-cent solution of uranyl nitrate in water or a 5-per-cent solution of uranyl acetate in water made slightly acid with acetic acid.

Alkaline Lead Nitrate Solution.—Into 100 cc. of KOH solution (56 g. in 140 cc. of water) pour a saturated solution of lead nitrate (250 g. in 500 cc. of water) until the precipitate ceases to redissolve, stirring constantly while mixing. Let settle, filter through asbestos, and dilute the clear filtrate with an equal volume of water. About 3 volumes of the lead nitrate solution will be required for one of the KOH.

Ammoniacal Cadmium Chloride or Zinc Sulfate Solution.—Dissolve 8 g. of cadmium chloride in 200 cc. of water and add 200 cc. of NH_4OH (sp. gr. 0.90), or, dissolve 200 g. of zinc sulfate in 1080 cc. of water and 920 cc. of NH_4OH (sp. gr. 0.90).

Standard Potassium Iodate Solution.—Dissolve 3.6 g. of KIO_3 and 39 g. of KI in 1000 cc. of water. For general work the theoretical sulfur titer of this solution should be used; for special work, the solution may be standardized against like material, such as a lithopone of known sulfide sulfur content. The theoretical titer is based on standard $Na_2C_2O_4$ and is obtained as follows: To 300 cc. of water in a 600-cc. flask, preferably glass stoppered, add 10 cc. of concentrated HCl (sp. gr. 1.19) and 1 g. of KI. Cool and add 10 cc. of 0.1 *N* $KMnO_4$ solution which has been standardized against $Na_2C_2O_4$. Swirl gently, stopper, and let stand for five minutes. Titrate the liberated iodine with standard $Na_2S_2O_3$ solution until the color fades. Then add 10 cc. of starch solution and continue the titration until the blue color is destroyed. Repeat the titration with the sole difference that 10 cc.

of the iodate solution is substituted for the $KMnO_4$ solution. Calculate the normality of the iodate solution.

Starch Indicator for Sulfur Titration.—(1) To 1000 cc. of boiling water, add a cold suspension of 6 g. of starch in 100 cc. of water and boil vigorously for five minutes. Cool the solution, add 6 g. of $ZnCl_2$ dissolved in 50 cc. of cold water, thoroughly mix and set aside for 24 hours. Decant the clear supernatant liquid into a suitable container, add 3 g. of KI, and mix thoroughly. (2, Optional.) Prepare an emulsion of 6 g. of soluble starch in 25 cc. of water, add a solution of 1 g. of NaOH in 10 cc. of water, and stir the solution until it gelatinizes. Dilute to 1000 cc. with water, add 3 g. of KI, and mix thoroughly.

Starch-Iodate Paper.—Impregnate filter paper with a solution obtained by heating 2 g. of starch with 100 cc. of water, and, after solution, adding 0.2 g. of KIO_3 dissolved in 5 cc. of water.

Standard Iodine Solution for SO_2.—Place 15 to 20 g. of pure KI in a liter flask, dissolve in as little water as possible, and then add about 6.4 g. of resublimed iodine. Shake until the iodine is all dissolved, dilute to the mark with water, and mix. This solution is approximately 0.05 N and is standardized against 0.05 N $Na_2S_2O_3$ to obtain its true normality.

Standard Sodium Thiosulfate Solution for SO_2.—Prepare and standardize as described above, except that 12.42 g. of pure crystallized $Na_2S_2O_3 \cdot 5H_2O$ are used or the 0.1 N solution may be diluted with an equal volume of cold CO_2-free water.

METHODS

WATER (NOTE 1)

Mix 100 g. of the paint in a 250-cc. flask with 75 cc. of toluene. Place the flask in an oil bath, connect with condenser, apply heat to the bath, and distil until about 50 cc. of distillate have been collected in a graduate. The temperature in the flask should be then about 105 to 110° C. The number of cubic centimeters of water collected under the toluene in the receiver is the percentage of water in the paint.

VOLATILE THINNER

Weigh accurately from 3 to 5 g. of the paint into a tared flat-bottomed dish about 8 cm. in diameter, spreading the paint over the bottom. Heat at 105 to 110° C. for one hour, cool, and weigh. Calculate the loss in weight as percentage of water and volatile thinner, subtract from this the percentage of water (1), and report the remainder as volatile thinner.

NATURE OF THE THINNER

Transfer about 150 g. of the paint to a 500-cc. flask fitted with a 2-hole cork stopper carrying a spray trap connected with a vertical condenser. Through the other hole in the stopper pass an influx tube for steam. (This tube should dip below the surface of the paint.) Heat the flask in an oil bath or an air bath at 100° C. and pass through it a current of steam; with the steam still passing through, raise the temperature of the bath to 130° C. Catch the distillate in a small separatory funnel; continue distillation until 300 cc. of water has been condensed. Portions of this water may be drawn from the cock of the separatory funnel from time to time, but care must be taken not to draw out any of the volatile thinner. Let the distillate stand until it separates into two layers, then draw off the water, and filter the volatile thinner through a dry filter paper into a dry flask. If the thinner is apparently turpentine, examine the distillate by the methods described in Sections 6 to 11, inclusive, of the Standard Methods of Sampling and Testing Turpentine (Serial Designation: D 233) of the American Society for Testing Materials.[1] If the thinner is a mixture of turpentine and mineral spirits, an approximate determination of the amount of turpentine may be made by the polymerization test specified for under turpentine. It should be noted that turpentine is slightly soluble in water (about 0.3 to 0.4 cc. per 100 cc. of water).

To test for benzol, add a few drops of the distillate to a small quantity of a mixture of concentrated HNO_3 and concentrated H_2SO_4, and heat cautiously. The characteristic odor of nitrobenzol will be noted if benzol is present.

If the thinner is apparently all mineral spirits, no further examination is necessary.

PERCENTAGE OF PIGMENT

Strain a portion of the well-mixed sample through a No. 80 sieve to remove any skins and weigh accurately about 15 g. of the strained paint in a weighed centrifuge tube. Add 20 to 30 cc. of "extraction mixture" (see "Reagents"), mix thoroughly with a glass rod, wash the rod with more of the extraction mixture, and add enough of the reagent to make a total of 60 cc. in the tube. Place the tube in the container of a centrifuge, surround the tube with water, and counterbalance the container of the opposite arm with a similar tube, or a tube with water. Whirl at a moderate speed until well settled. Decant the clear supernatant liquid, repeat the extraction twice with 40 cc. of extraction mixture and once with 40 cc. of ethyl ether. After drawing off the ether, set the tube in a beaker of water at about 80° C. or on top of a warm oven for 10 minutes, then in an oven at 105 to 110° C. for two hours. Cool, weigh, and calculate the percentage of pigment. Grind the pigment to a fine powder, pass through a No. 80 sieve to remove any skins, and preserve in a stoppered bottle.

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 269.

PERCENTAGE OF NON-VOLATILE VEHICLE

Add together the percentages of water, of volatile thinner, and of pigment, and subtract the sum from 100. Report the remainder as non-volatile vehicle.

TESTING NON-VOLATILE VEHICLE

(a) *Preparation of fatty acids.*

To about 25 g. of the paint in a porcelain casserole, add 15 cc. of aqueous sodium hydroxide (see "Reagents") and 75 cc. of ethyl alcohol, mix and heat uncovered on a steam bath until all volatile thinner is driven off and saponification is complete. Add 100 cc. of water, boil, add H_2SO_4 (sp. gr. 1.2) (8 to 10 cc. in excess), boil, stir, and transfer to a separatory funnel to which some water has been previously added. Draw off as much as possible of the acid aqueous layer and any insoluble or precipitated matter, wash once with water, then add 50 cc. of water and 50 cc. of ethyl ether. Shake very gently with a whirling action to dissolve the fatty acids in the ether, but not so violently as to form an emulsion. Draw off the aqueous layer and wash the ether layer with one 15-cc. portion of water and then with 5 cc. portions of water until free from sulfuric acid. Then draw off the water layer completely. Transfer the ether solution to a dry flask and add 25 to 50 g. of anhydrous sodium sulfate. Stopper the flask and let stand with occasional shaking at a temperature below 25° C. until the water is completely removed from the ether solution, which will be shown by the solution becoming perfectly clear above the solid sodium sulfate. Decant this clear solution, if necessary, through a dry filter paper into a dry 100-cc. Erlenmeyer flask. Pass a rapid current of dry air (pass through a $CaCl_2$ tower) into the mouth of the Erlenmeyer flask and heat to a temperature below 75° C. on a dry hot plate until the ether is entirely driven off. It is important to follow all of the details, since ether generally contains alcohol, and after washing with water always contains water. It is very difficult to remove water and alcohol by evaporation from fatty acids, but the washing of the ether solution and subsequent drying with anhydrous sodium sulfate removes both water and alcohol. Ether, in the absence of water and alcohol, is easily removed from fatty acids by gentle heat.

If the pigment settles out rapidly in a sample of the paint on standing so that sufficient vehicle can be poured off; or, if sufficient vehicle is obtained by centrifuging the paint, it will be advantageous to saponify this separated vehicle and liberate and prepare the fatty acids as described.

The fatty acids prepared as above should be kept in a stoppered flask and examined at once.

(*b*) *Test for mineral oil and other unsaponifiable matter.*

Place 10 drops of the fatty acids Method (*a*), in a 50-cc. test tube, add 5 cc. of alcoholic soda (see "Reagents"), boil vigorously for five minutes, add 40 cc. of water, and mix; a clear solution indicates that not more than traces of unsaponifiable matter are present.

(*c*) *Iodine number of fatty acids* (Note 2).

Place a small quantity of the fatty acids Method (*a*), in a small weighing burette or beaker. Weigh accurately. Transfer by dropping about 0.15 g. (0.10 to 0.20 g.) into a 500-cc. bottle having a well ground glass stopper, or an Erlenmeyer flask having a specially flanged neck for the iodine test. Reweigh the burette or beaker and determine the amount of sample used. (If desired the sample may be weighed in a small wide-mouthed vial and the vial containing the weighed sample placed in the bottle or flask.) Add 10 cc. of chloroform. Whirl the bottle or flask to dissolve the sample. Add 10 cc. of chloroform to two empty bottles or flasks like that used for the sample. Add to each bottle or flask 25 cc. of the Wijs solution (see "Reagents") and let stand with occasional shaking for 1 hour in a dark place at a temperature of from 21 to 23° C. Add 10 cc. of the 15-per-cent potassium iodide solution and 100 cc. of water, and titrate with standard sodium thiosulfate solution (see "Reagents"), using starch as indictaor. The titrations on the two blank tests should agree within 0.1 cc. From the difference between the average of the blank titrations and the titration on the sample and the iodine value of the thiosulfate solution, calculate the iodine number of the sample tested. (Iodine number is centigrams of iodine to 1 g. of sample.)

(*d*) *Rosin.*

Liebermann-Storch Test.[1]—To about 1 g. of the fatty acids add 15 cc. of acetic anhydride and shake until solution is complete. Pour a few drops of this solution on a white porcelain plate (a crucible cover serves well) and add a drop of H_2SO_4 (sp. gr. 1.53). A fugitive violet color indicates rosin.

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[1] "Chemical Technology and Analysis of Oils, Fats and Waxes," by J. Lewkowitsch, Vol. 1, p. 623 (1921).

Halphen-Hicks Test.[1]—Place about 1 g. of the fatty acids in a cavity of an ordinary porcelain color-reaction plate. Fill the cavity with a solution of one part by volume of phenol dissolved in two parts by volume of carbon tetrachloride. Stir the mixture. Fill another cavity of the porcelain plate with a solution of one part by volume of bromine and four parts by volume of carbon tetrachloride. Cover the whole plate with an inverted watch glass. If rosin is present the bromine fumes develop very soon an indigo blue color which persists for some time.

ANALYSIS OF PIGMENT

(*a*) *Qualitative Analysis.*

A complete qualitative analysis, following the well-established methods, should be made and the quantitative scheme modified as required. Add acetic acid slowly to the pigment until all carbonate is decomposed (noting whether any hydrogen sulfide is evolved); then add a large excess of acid ammonium acetate solution (see "Reagents"), boil, filter, and test the filtrate for metals other than lead and zinc (especially calcium and barium). The absence of calcium in this filtrate indicates that the extending pigments contain no calcium carbonate or calcium sulfate; the absence of barium indicates that the extending pigments contain no barium carbonate (Note 5). Wash the matter insoluble in acid ammonium acetate solution with another portion of this solution, and finally with hot water. This insoluble matter is dried, ignited, and tested for siliceous matter, barium sulfate, and titanium compounds. To test for the latter, place a small amount of the insoluble matter, or of the original sample (about 0.5 g.), in a 250-cc. Pyrex glass beaker; add 20 cc. of concentrated H_2SO_4 and 7 to 8 g. of ammonium sulfate. Mix well, and boil for a few minutes. A residue denotes the presence of silica or siliceous matter. Cool the solution, dilute with 100 cc. of water, heat to boiling, settle, filter, wash with hot 5-per-cent sulfuric acid until free from titanium. The residue may be tested for lead, barium, and silica. Add hydrogen peroxide to a small portion of the filtrate; a clear yellow-orange color indicates the presence of titanium. Boil another portion of the filtrate with metallic tin or zinc; a pale blue to violet coloration indicates titanium. Treat another portion (about 1 g.) of the pigment with 20 cc. of HCl (1:1) and note whether any H_2S is evolved; boil the solution for about 5 minutes, add about 25 cc. of hot water, filter, and wash with hot water. Render a small portion of the filtrate alkaline with NH_4OH, acidify with HCl, and add a little $BaCl_2$ solution; a white precipitate ($BaSO_4$) indicates the presence of a soluble sulfate. To another portion of the filtrate add a little H_2SO_4; a white precipitate indicates the presence of lead, soluble barium or both (some $CaSO_4$ may also separate); filter, wash to remove free acid, and treat the precipitate with a few drops of KI solution; the formation of yellow PbI_2 indicates the presence of lead. The white precipitate may also be treated with H_2S water; the formation of black PbS indicates the presence of lead. To another portion of the original filtrate add NH_4OH until alkaline, render slightly acid with acetic acid, heat to boiling, and add a little $K_2Cr_2O_7$ solution; a yellow or orange-yellow precipitate indicates the presence of lead, soluble barium or both. To another portion of the original filtrate add a few drops of $K_4Fe(CN)_6$ solution; a white precipitate with a blueish tinge indicates the presence of zinc. Pass into the remaining portion of the original filtrate a current of H_2S for 5 to 10 minutes, add an equal volume of water and pass H_2S into the solution for about 5 minutes; filter, wash with H_2S water; then digest the precipitate with ammonium polysulfide, filter, acidify the filtrate with HCl and warm; the presence of antimony is indicated by the separation of an orange colored precipitate. The filtrate from the H_2S precipitate may be tested for barium, calcium, and magnesium in the usual manner.

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[1] *Journal of Industrial and Engineering Chemistry*, Vol. 3, p. 86 (1911).

(*b*) *Quantitative Analysis.*

(1) *Single Pigments:*

If the sample is a single pigment, follow the method described in the Standard Methods of Routine Analysis of White Pigments (Serial Designation: D 34) of the American Society for Testing Materials[1] for the particular pigment in hand.

(2) *Mixed or Composite Pigments:*

Moisture (Note 3) (*Matter Volatile at 105–110° C.*).—Place 1 to 2 g. of the sample in a wide-mouth, short weighing tube provided with glass stopper. Heat with the stopper removed for 2 hours at a temperature between 105 and 110° C. Insert the stopper, cool, and weigh. Calculate the loss in weight as moisture (matter volatile at 105 to 110° C.).

Loss on Ignition.—Ignite 1 g. of the pigment in a porcelain crucible over a Meker burner to constant weight (Note 4).

Insoluble Matter.—Moisten 1 g. of the sample with a few drops of alcohol, cover, add 40 cc. of HCl (1:1), boil gently for 5 to 10 minutes. Wash off cover, evaporate to dryness, and heat at about 150° C. for one-half to one hour to dehydrate the residue. Moisten the residue with 4 cc. of concentrated HCl, allow to stand a few minutes, dilute with 100 cc. hot water, boil a few minutes, filter hot through paper, wash with hot water (till washings give no test for lead and chlorine). Ignite the paper and residue in a platinum or porcelain crucible, cool, and weigh total insoluble matter (Note 5). (The insoluble matter may be filtered off on a Gooch crucible, washed with hot water, dried at 105° C., cooled, and weighed; then ignited, cooled, and weighed, when it is desired to get the loss on ignition (combined water, organic matter, etc.) of same, or the insoluble matter is not to be further examined.) If the sample contains titanium pigment, practically all of the TiO_2 will be found in the insoluble matter along with $BaSO_4$ and siliceous matter. The TiO_2 may be determined in the insoluble matter or in a separate portion of the original sample by the method described in Sections 8, 10 and 11 of the Standard Methods of Routine Analysis of Titanium Pigments (Serial Designation: D 186) of the American Society for Testing Materials.[1] To determine $BaSO_4$, mix the ignited insoluble matter with about 10 times its weight of anhydrous sodium carbonate (grinding the mixture in an agate mortar if necessary), and fuse the mixture in a covered platinum crucible, heating about one hour. Let cool, place crucible and cover in a 250-cc. beaker, add about 100 cc. of water, and heat until the melt is disintegrated. Filter on paper (leaving crucible and cover in beaker) and wash the beaker and filter thoroughly with hot water to remove soluble sulfates. Place the beaker containing the crucible and cover under the funnel, pierce the filter with a glass rod, and wash the residue into the beaker by means of a jet of hot water. Wash the paper with hot dilute HCl (1:1) and then with hot water. Remove crucible and cover, washing them with a jet of hot water and removing any adhering precipitate. Add cautiously 20 cc. of concentrated H_2SO_4 and evaporate until fumes of H_2SO_4 are evolved and the precipitated matter is dissolved. *Cool,* add cautiously, with stirring, about 100 cc. of water, and boil a few minutes. Let the precipitate settle, filter on a weighed Gooch crucible, wash with hot water, ignite, cool, and weigh as $BaSO_4$. Subtract the sum of the percentages of $BaSO_4$ and TiO_2 from the percentage of total insoluble matter and report the result as the percentage of insoluble siliceous matter (Note 6).

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 305.

If it is desired to examine the siliceous matter, unite the filtrates from the Na_2CO_3 fusion and the $BaSO_4$ precipitate, acidify with HCl, evaporate to dryness, and proceed as in a silicate analysis, taking cognizance of any TiO_2 that may be found, if titanium pigment were originally present.

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 341.

Total Lead (Antimony).—Unite the filtrate and washings (total volume 150 to 200 cc.) from the total insoluble matter, pass H_2S into the solution until it is saturated, add an equal volume of water, and again saturate with H_2S. Filter, wash with water containing a little hydrogen sulfide, dissolve in hot HNO_3 (1:3), washing the paper with hot water; add 10 to 20 cc. of H_2SO_4 (1:1), evaporate until copious fumes of sulfuric acid are evolved; cool, add about 75 cc. of water, and then about 75 cc. of 95-per-cent ethyl alcohol. Stir; let settle, filter on a Gooch crucible, wash with dilute alcohol, dry in an oven at 105 to 110° C.; or, ignite gently in a radiator[1] or muffle, cool, and weigh as $PbSO_4$. Calculate to PbO (Note 7).

If the pigment contains antimony, filter and wash the sulfide precipitate as above; then wash the precipitate with a fine jet of H_2O from the paper into a porcelain dish or casserole, add 25 cc. of ammonium polysulfide (see "Reagents"), cover the vessel, and warm the mixture at 40 to 60° C. for 10 to 15 minutes with frequent stirring. Wash off cover, filter through the paper used in the first case, and wash with 2 to 3-per-cent Na_2S or $(NH_4)_2S$ solution. Discard the filtrate. Dissolve the residue in hot dilute HNO_3 (1:3), and determine the lead as $PbSO_4$, as described above. Or, the original sulfide precipitate may be discarded and the lead determined on a separate portion of the pigment as follows: To 1 g. of the sample in a covered beaker, add 40 cc. of HCl (1:1) and boil gently for 5 to 10 minutes. Wash off cover and evaporate to dryness. Moisten the residue with a few drops of HCl, add about 50 cc. of hot water, boil a few minutes, filter hot through paper, and wash with hot water until washings give no test for lead. (If the sample contains no insoluble matter, the filtration is omitted.) To the filtrate add 20 cc. of H_2SO_4 (sp. gr. 1.84) and evaporate until dense white fumes of H_2SO_4 are copiously evolved. Allow to cool, but not below 60° C., and then add slowly 50 cc. of water while the solution is agitated. Heat to boiling for several minutes in order to insure complete solution of antimony sulfate. Allow the $PbSO_4$ to settle out until the supernatant liquid is clear, not letting the temperature fall below 60° C. If the liquid does not clear quickly it must be heated longer. When clear, pour the solution through a weighed porcelain Gooch crucible with asbestos mat, decanting the solution as completely as possible without allowing more than a very small amount of $PbSO_4$ to go over into the crucible. Now add 10 cc. more of H_2SO_4 (sp. gr. 1.84) to the $PbSO_4$ in the original beaker, and boil for several minutes. Cool, add slowly 30 cc. of water, and again heat to boiling for a few minutes; allow the solution to cool to about

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[1] *U. S. Geological Survey Bulletin 700*, p. 33 (1919).

60° C. and completely transfer the $PbSO_4$ to the Gooch crucible. Wash with "lead acid" (see "Reagents") to remove soluble sulfates and finally wash free of acid with dilute alcohol (equal parts of ethyl alcohol or denatured alcohol and water). Dry in an oven at 105 to 110° C., or, ignite gently in a radiator or muffle. Calculate to PbO, or determine as chromate as described below.

If soluble compounds of barium or calcium are present, $BaSO_4$ and $CaSO_4$ will be included with the $PbSO_4$. If soluble SiO_2 is present, it will also be included with the $PbSO_4$. In such cases, the $PbSO_4$ precipitate after washing with dilute alcohol may be dissolved in acid ammonium acetate (see "Reagents") and the lead determined as $PbCrO_4$, as described below. For ordinary work, the amount of $BaSO_4$ dissolved by the acetate treatment may be disregarded.

If the pigment contains no soluble antimony, barium, or calcium compounds, the lead may be determined directly on the original pigment, as follows: To 1 g. of the sample in a covered beaker, add 25 cc. of HNO_3 (1:1), and boil gently a few minutes. Wash off cover, evaporate to dryness on a steam bath, moisten with HNO_3, add hot water, and heat a few minutes. Filter and wash with hot water until washings are lead-free. Add 10 to 20 cc. of H_2SO_4 (1:1) to the clear solution, evaporate and determine lead as $PbSO_4$, as above described.

In the absence of soluble compounds of antimony, iron, aluminum, and barium, the following procedure may be used: Treat 1 g. of the original pigment with 25 cc. of HNO_3 (1:1) and proceed as above. To the clear solution, diluted to 200 cc. add NH_4OH in slight excess, acidify with acetic acid, and add 4 to 6 cc. more of this acid; heat to boiling and add 10 to 15 cc. of a 10-per-cent solution of $K_2Cr_2O_7$. Heat until the yellow precipitate assumes an orange color, let settle and filter on a weighed Gooch crucible, wash by decantation until the washings are colorless, finally transferring all of the precipitate. Then wash with 95-per-cent ethyl alcohol and then with ether; dry to constant weight at 110° C., cool, and weigh $PbCrO_4$. Calculate to PbO.

Antimony Oxide.—Transfer 0.3 g. of a straight antimony oxide pigment, or 0.5 g. of a mixed pigment, to a 500-cc. Pyrex Erlenmeyer flask, add 15 cc. of water and 25 cc. of concentrated HCl (sp. gr. 1.19). Cover with a watch glass, warm on the steam bath 10 to 15 minutes to dissolve the antimony oxide, wash off cover, add 250 cc. of water, and 15 cc. of concentrated H_2SO_4 (sp. gr. 1.84). Boil 2 minutes, cool to 10 to 15° C., and titrate to a faint pink tint with 0.1 N $KMnO_4$ solution (see "Reagents"). Calculate to Sb_2O_3.

The above procedure gives only the antimony in the *ous* condition. The following method gives the total antimony (*ous* and *ic* forms):

Transfer 0.3 g. of a straight antimony oxide pigment, or 0.5 g. of a mixed pigment, to a 500-cc. Pyrex Erlenmeyer flask, add 15 cc. of H_2SO_4 (sp. gr. 1.84), 10 g. of K_2SO_4, and a 9-cm. filter paper (to furnish carbon to act as a reducing agent). Place a funnel in the neck of the flask, and heat until the solution becomes colorless. Cool, wash off the funnel, dilute to 250 cc. with water, add 20 cc. of concentrated HCl, and boil 2 minutes; cool to 10 to 15° C., and titrate to a faint pink tint with 0.1 *N* $KMnO_4$ solution (Note 8).

Antimony Oxide (in the presence of appreciable amounts of iron).—Treat 1 g. of the mixed pigment, or 0.3 g. of a straight antimony oxide pigment, in a covered 250-cc. beaker with 5 cc. of water and 20 cc. of HCl (sp. gr. 1.19); heat on the steam bath for 15 minutes, cool, wash off cover, add 3 g. of tartaric acid and 100 cc. of hot water, and digest a few minutes. Filter, catching the filtrate in a 500-cc. Pyrex Erlenmeyer flask; wash thoroughly with hot water, dilute to 300 cc. with hot water, and pass in H_2S until the precipitation is complete. (If the sample contains no insoluble matter, disolve directly in a 500-cc. Pyrex Erlenmeyer flask, add tartaric acid, dilute, and pass in H_2S.) Filter, wash with water containing H_2S until free from HCl, return paper and precipitate to the Erlenmeyer flask, add 15 cc. of H_2SO_4 (sp. gr. 1.84) and 10 g. of K_2SO_4, place a funnel in the neck of the flask, and heat until the solution is colorless. Cool, wash off the funnel, dilute to about 250 cc. with water, add 20 cc. of HCl (sp. gr. 1.19), boil for 2 or 3 minutes, cool to about 10° C., and titrate to a faint pink tint with 0.1 *N* $KMnO_4$ solution (see "Reagents"). Calculate the total antimony to Sb_2O_3 (Note 9).

Soluble Barium.—Boil the combined filtrate and washings, reduced in volume by evaporation if need be, from the PbS precipitate (Total Lead) to expel H_2S. Add a slight excess of H_2SO_4 (1:4) over the amount required to precipitate the barium, heat to boiling, let stand on a steam bath about one hour, filter on a weighed Gooch crucible, wash with hot water, dry, ignite, cool, and weigh $BaSO_4$ (Notes 5 and 10). Calculate to BaO.

Alumina (Fe_2O_3, TiO_2, P_2O_5).—Boil the filtrate from the PbS to expel H_2S, add a few drops of HNO_3, and continue the boiling a few minutes to oxidize any iron that may be present. In case soluble barium was present, use the filtrate from that determination. To the solution containing at least 5 g. of NH_4Cl per 200 cc. of solution, or an equivalent amount of HCl, add a few drops of methyl red (0.2-percent alcoholic solution) and heat just to boiling. Carefully add dilute NH_4OH drop by drop until the color of the solution changes to a distinct yellow. Boil the solution for one to two minutes and filter at once. Wash the precipitate thoroughly with hot 2-per-cent NH_4Cl solution (Note 11). Ignite the precipitate, cool, and weigh as Al_2O_3 (Note 12).

Total Zinc.—(*a*) To the combined filtrate and washings from the alumina precipitate, add sufficient NH_4Cl to give 5 g. per 100 cc. of solution, and then add 1 g. of ammonium acetate.[1]

Render slightly acid with acetic acid and pass in a current of H_2S to saturation. Allow the precipitate to settle completely, filter on paper, and wash with a 2-per-cent solution of acetic acid saturated with H_2S. Transfer the precipitate and filter to the vessel in which the precipitation was effected, add 30 cc. of water and 10 cc. of concentrated HCl, heat until all zinc is in solution, add 200 cc. of water and a small piece of litmus paper; add strong NH_4OH until slightly alkaline, render just acid with HCl, then add 3 cc. of concentrated HCl, heat nearly to boiling, and titrate with standard potassium ferrocyanide solution as in standardizing that solution (see "Reagents").

(*b*) Zinc may be determined directly on the original sample as follows (Note 13): Weigh accurately about 1 g. (or an amount that will give a burette reading approximately equal to that obtained in the standardization) of the pigment, transfer to a 400-cc. beaker, add 30 cc. of HCl (1:2), boil a few minutes, add 200 cc. of water and a small piece of litmus paper; add strong NH_4OH until slightly alkaline, render just acid with HCl, then add 3 cc. of concentrated HCl, heat nearly to boiling, and titrate with standard $K_4Fe(CN)_6$ solution as in standardizing that solution (see "Reagents").

(*c*) When iron is present, total zinc may be determined directly on the original sample as follows (Note 13): Weigh accurately about 1 g. (or an amount that will give a burette reading approximately equal to that obtained in the standardization) of the pigment, transfer to a 250-cc. beaker, moisten with alcohol, add 30 cc. of HCl (1:2), boil for 2 or 3 minutes, and add about 100 cc. of water. Add about 2 g. of NH_4Cl, make slightly alkaline with NH_4OH, heat to boiling, let settle on steam bath, filter into a 400-cc. beaker and wash the residue once with hot water. Remove the 400-cc. beaker and pour dilute HCl on the residue, catching the filtrate therefrom in the 250-cc. beaker, wash a few times with hot water. Add to this filtrate 1 g. of NH_4Cl and make slightly alkaline with NH_4OH, boil, let settle, filter on paper used for first filtration, and wash thoroughly with hot water, catching the filtrate and washings in the 400-cc. beaker containing the first filtrate. Add a small piece of litmus paper, acidify with HCl, add 3 cc. of concentrated HCl, heat nearly to boiling, and titrate with standard $K_4Fe(CN)_6$ as above.

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[1] F. A. Gooch, "Representative Procedures in Quantitative Chemical Analysis," 1st Ed., p. 107.

(*d*) With pigments containing ZnO and ZnS the ZnO may be determined as follows: Weigh accurately 2.5 g. of the pigment, transfer to a 250-cc. graduated flask, moisten with a few drops of alcohol, add about 200 cc. of 2 to 3-per-cent acetic acid, shake vigorously and let stand for 30 minutes at room temperature, shaking once every 5 minutes. Then let stand at room temperature at least 5 hours, preferably overnight. Fill to the mark with 2 to 3-per-cent acetic acid, mix, filter through a dry paper, discard the first 25 cc. and transfer 100 cc. of the filtrate (corresponding to 1 g.) to a 400-cc. beaker. To the clear solution add 30 cc. of HCl (1:2), 100 cc. of H_2O, and a small piece of litmus paper; add strong NH_4OH until slightly alkaline, render just acid with HCl, then add 3 cc. of concentrated HCl, heat nearly to boiling, and titrate with $K_4Fe(CN)_6$ as above. Calculate the percentage of ZnO (any $ZnCO_3$ or $ZnSO_4$ is included in the ZnO). Subtract this result from the percentage of total Zn as ZnO, and calculate the difference to ZnS.

Soluble Calcium.—Heat the united filtrate and washings, reduced in volume if need be, from the ZnS precipitate, to boiling, add 1 cc. of NH_4OH and an excess of a hot saturated ammonium oxalate solution. Continue the boiling until the precipitate becomes granular; let stand about one hour, filter, and wash with hot water. Ignite, cool, and weigh as CaO (Notes 5, 14, 15); or, place the beaker in which the precipitation was made under the funnel, pierce the apex of the filter with a stirring rod and wash the precipitate into the beaker with hot water, pour warm dilute H_2SO_4 (1:4) through the paper and wash a few times. Add about 30 cc. of dilute H_2SO_4 (1:4), dilute to about 250 cc., heat to 90° C. and titrate at once with standard (0.1 *N*) $KMnO_4$ solution (the temperature of the solution should not be below 60° C. when the end point is reached. See "Reagents"). Calculate to CaO (Notes 5, 14, 15). (The Fe value of $KMnO_4 \times 0.502 =$ CaO value.)

Soluble Magnesium.—Acidify the filtrate from the calcium precipitate with HCl, add 10 cc. of a saturated solution of $Na(NH_4)HPO_4$ and NH_4OH drop by drop, with constant stirring. When the crystallin $(NH_4)MgPO_4$ has formed, add 5 cc. excess of NH_4OH. Allow the solution to stand in a cool place for not less than 4 hours, preferably overnight (Note 16); filter and wash with water containing 2.5 per cent of NH_3. Dissolve the precipitate in a small quantity of hot dilute HCl, dilute the solution to about 100 cc. with water, add 1 cc. of a saturated solution of $Na(NH_4)HPO_4$ and NH_4OH drop by drop, with constant stirring, until the precipitate is again formed as described, and then add 5 cc. excess of NH_4OH. Let the precipitate stand in a cool place for not less than 2 hours, filter on a Gooch crucible, wash with water containing 2.5 per cent of NH_3, ignite, cool, and weigh as $Mg_2P_2O_7$ (Note 17). Calculate to MgO.

Carbon Dioxide.—Use from 1 to 2 g. of the pigment depending upon the probable CO_2 content, following either of the methods described under the Determination of Carbon Dioxide in the Tentative Methods of Chemical Analysis of Limestone, Quicklime and Hydrated Lime (Serial Designation: C 25 - 27 T) of the American Society for Testing Materials[1] (Note 18).

Total Soluble Sulfur Compounds (Note 5).—Treat 1 g. of the pigment in a 400-cc. beaker with 10 cc. of H_2O, 10 cc. of strong HCl saturated with bromine, and 5 g. of NH_4Cl, digest (covered) on a steam bath for 5 minutes, dilute with hot water to about 200 cc., boil for 5 minutes, filter to separate any insoluble matter, and wash thoroughly with hot water. Nearly neutralize the clear solution in a covered beaker with NaOH solution, complete the neutralization with dry Na_2CO_3 and add about 2 g. more of this reagent. Boil 10 to 15 minutes, wash off cover, let settle, filter, and wash with hot water. Re-dissolve the precipitate in HCl (1:1), reprecipitate with Na_2CO_3 as above, filter, and wash thoroughly with hot water. Acidify the united filtrates with HCl, adding about 1 cc. in excess. Boil to expel bromine, and to the clear boiling solution add slowly with stirring an excess of a 10-per-cent $BaCl_2$ solution. Let stand on a steam bath for at least 1 hour, filter on a weighed Gooch crucible, wash thoroughly with boiling water, dry, ignite at a dull red heat, cool, and weigh as $BaSO_4$. This will include soluble sulfates, SO_3 formed from SO_2 and the SO_3 that is formed from sulfide sulfur (Note 10).

Soluble Sulfate (Note 5).—Treat 1 g. of the pigment with 10 cc. of H_2O and 10 cc. of concentrated HCl and 5 g. of NH_4Cl. Boil until H_2S is expelled, adding more HCl (1:1) if necessary; dilute with hot water to about 200 cc., boil for 5 minutes, filter to separate any insoluble matter, and wash thoroughly with hot water. Nearly neutralize the clear solution with NaOH solution and make a double precipitation with Na_2CO_3, as in preceding method, finally weighing as $BaSO_4$, as described above (Note 10).

Sulfide Sulfur[2] (Note 19).—Place 0.5 to 1 g. of the pigment in a flask with about 10 g. of "feathered" or mossy zinc, add 50 cc. of water; insert a stopper carrying a separatory funnel and an exit tube. Run in 50 cc. of concentrated HCl from the funnel, having previously connected the exit tube to two absorption flasks in series; the first flask contains 100 cc. of alkaline lead-nitrate solution (see "Reagents"), the second flask, 50 cc. of the same solution as a safety device. After all of the acid has run into the evolution flask, heat slowly, finally boiling until the first appearance of steam in the first absorption flask. Disconnect, let the lead sulfide settle, filter, wash with cold water, then with hot water till neutral to litmus paper and washings give no test for lead. Dissolve the PbS precipitate in hot, dilute HNO_3, and determine the lead as $PbSO_4$. Calculate to S. For very rapid work, the evolved H_2S may be absorbed in an ammoniacal $CdCl_2$ or $ZnSO_4$ solution (see "Reagents") contained in 2 flasks connected in series, the contents of the absorption flasks washed into a vessel with cold water and diluted to about one liter, acidified with concentrated HCl and titrated with standard potassium iodate solution (see "Reagents"), using starch indicator (see "Reagents").

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 776 (1927); also 1928 Book of A.S.T.M. Tentative Standards, p. 211.

[2] Evolution Method of W. G. Scott, "White Paints and Painting Materials," p. 257; **see also** Blair, "The Chemical Analysis of Iron."

Sulfur Dioxide (Note 20).—Transfer 10 g. of the pigment to a suitable flask, insert a stopper fitted with a separatory funnel and a spray trap delivery tube (Note 21), and attach the latter to a condenser. Place about 150 cc. of HCl (1:3) in the funnel, the stopcock being closed (Note 22), connect the other end of the condenser with a delivery tube which passes through a 2-hole stopper and extends nearly to the bottom of an absorption flask; through the other hole of the stopper connect a tube or flask to serve as a safety device. Place 25 cc. of 0.05 *N* iodine solution (see "Reagents") in the absorption flask (dilute with water if need be) and 20 cc. of 10-per-cent KI solution in the safety tube; fit stopperin the absorption flask. Open the stopcock and allow the acid to slowly enter the flask. Before all of the acid is admitted, air (washed with NaOH solution) is forced through the top of the separatory funnel (about 2 bubbles per second in the KI solution). Boil the solution 3 minutes with the air passing through, then remove the source of heat and pass air through for 30 minutes. Disconnect the absorption vessels, wash the KI solution into the iodine solution, and titrate at once with 0.05 *N* $Na_2S_2O_3$ solution, using starch indicator. Run a blank determination in exactly the same manner except for the omission of the pigment. Subtract this figure from the previous one and calculate the final result to SO_2 (1 cc. 0.05 N I = 0.0016 g. SO_2).

Matter Soluble in Water.—Transfer 2.5 g. of the pigment to a graduated 250-cc. flask, add 100 cc. of water, boil for 5 minutes, cool, fill to mark with water, mix, and allow to settle. Pour the supernatant liquid through a dry filter paper and discard the first 20 cc. Then evaporate 100 cc. of the clear filtrate to dryness in a weighed dish, heat for one hour at 105 to 110° C., cool, and weigh. Calculate the percentage. The nature of this may be determined by further examination, as the percentages of SO_3 and CaO may be indicative.

NOTES

1. A convenient apparatus for this determination is shown in Fig. 1 (*b*) of the Standard Method of Test for Water in Petroleum Products and Other Bituminous Materials (Serial Designation: D 95) of the American Society for Testing Materials.[1]

2. If appreciable amounts of rosin or of unsaponifiable matter are found to be absent in the vehicle of a paint, the iodine number of the fatty acids gives the best indication (though not proof) of the presence of linseed oil. An iodine number of less than 175 (Wijs) for the fatty acids is an indication that the nonvolatile vehicle was not pure linseed oil.

3. On an extracted and dried pigment, this determination is of little value. If the original paint contained gypsum, a part of the combined H_2O of the latter will be driven off in the drying of the extracted pigment and in the "moisture" determination.

4. This determination may serve as a rough or approximate check in many cases on the CO_2, H_2O, etc.

5. If the original sample contained $BaCO_3$ and $PbSO_4$, $CaSO_4$ or other soluble sulfate, the soluble Ba will form with the soluble sulfate a precipitate of $BaSO_4$ which will be determined as "insoluble matter." If the sample contained $SrSO_4$ or $SrCO_3$, some $SrSO_4$ may be counted as $BaSO_4$, some Sr will count as soluble barium, and some may be counted as CaO. This element is not separated, as it probably will not be encountered, or will be present as an impurity in the Ba and Ca compounds.

6. Any soluble Al_2O_3 (Fe_2O_3) and in most cases MgO, and sometimes some CaO, come from the siliceous pigment used. MgO generally denoted the presence of asbestine.

7. It is not possible to determine the amount of basic lead carbonate and lead sulfate when carbonates or soluble sulfates of other metals, such as calcium, are present. Also neither basic lead carbonate nor basic lead sulfate are definite compounds.

8. If the digestion with H_2SO_4 and K_2SO_4 (plus filter paper) is continued after the solution becomes colorless, some of the antimony may be oxidized from the *ous* to the *ic* condition. In such cases, cool, wash off the funnel, dilute to 100 cc. with water, add 1 to 2 g. of Na_2SO_3 and boil until all of the SO_2 is expelled. This is shown when no blue color is obtained with starch-iodate paper (see "Reagents"); the volume will be reduced about one-half. Dilute to 250 cc. with water, add 20 cc. of HCl (sp. gr. 1.19), and boil 2 minutes; cool to 10 to 15° C., and titrate to a faint pink tint with 0.1 *N* $KMnO_4$ solution. Calculate total Sb to Sb_2O_3. Subtract the Sb_2O_3 found by the procedure given in the first paragraph under Antimony Oxide from the total Sb_2O_3 and calculate the residual Sb_2O_3 to Sb_2O_5.

9. If the digestion with H_2SO_4 and K_2SO_4 (plus filter paper) is continued after the solution becomes colorless, some of the antimony may be oxidized from the *ous* to the *ic* condition. In such cases, cool, wash off the funnel, dilute to 100 cc. with water, add 1 to 2 g. of Na_2SO_3 and boil until all of the SO_2 is expelled. This is shown when no blue color is obtained with starch-iodate paper (see "Reagents"); the volume will be reduced about one-half. Dilute to 250 cc. with water, add 20 cc.

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[1] 1928 Supplement to Book of A.S.T.M. Standards, p. 149.

of HCl (sp. gr. 1.19), and boil 2 minutes; cool to 10 to 15° C., and titrate to a faint pink tint with 0.1 *N* $KMnO_4$ solution.

10. This will include any $BaSO_4$ that may have been dissolved as such. The weighed precipitate should be tested for $CaSO_4$, and if present, it should be removed by treating with hot dilute HCl, filtering, washing, igniting, and again weighing.

11. For very accurate work, or when the precipitate is large, the precipitate should be dissolved in HCl (1:1) and the precipitation repeated.

12. This precipitate may also contain Fe_2O_3, TiO_2, and P_2O_5.

13. If the sample contains antimony, it should be precipitated by H_2S in the hot acid solution, filtered off, washed, and the filtrate neutralized, etc., for zinc. The H_2S precipitate may also contain PbS. If no sulfide separation is made, any cadmium present will be counted as zinc.

14. Care must be exercised in this washing, as 1000 cc. of boiling water will dissolve over 0.01 g. of CaC_2O_4.

15. For more accurate work, the CaC_2O_4 precipitate should be ignited, cooled, cautiously moistened with water, redissolved in HCl and the solution diluted to 100 cc. Then NH_4OH should be added in slight excess, the liquid boiled, and filtered and washed if a precipitate appears. Then reprecipitate the Ca with NH_4OH and $(NH_4)_2C_2O_4$ as above, filter, wash, ignite, cool, and weigh; or, titrate as described.

16. The less the amount of magnesium present, the longer the precipitate must be allowed to settle.

17. If the sample contained manganese, it will be caught in large part with the $Mg_2P_2O_7$. If desired, Mn may be determined by dissolving the $Mg_2P_2O_7$ in HNO_3 and applying the bismuthate method.

18. If the sample is high in sulfide, *e. g.*, contains a high percentage of lithopone, grind 1 to 2 g. of the pigment with dry $K_2Cr_2O_7$, transfer to the evolution flask, add 50 cc. of water, and run in H_2SO_4 (1:1) from the separatory funnel. Or, place at the front of the purifying and drying train a tube containing acidified $CuSO_4$ solution, $KMnO_4$ solution, or CrO_3 solution.

19. The percentage of sulfide sulfur can be calculated from the percentages of total zinc and zinc soluble in 2 to 3 per cent acetic acid, assuming the sulfide to be ZnS. See Method (*d*) under determination of zinc.

20. This method is not applicable in the presence of sulfides decomposable under the conditions given.

21. A Knorr CO_2 apparatus is very convenient. In this case, the vertical condenser may be connected with an absorption tower containing the iodine solution, followed by the KI solution in a suitable tube.

22. To minimize, if not eliminate, any possible oxidation by the air, add about 1 g. (in one piece) of $NaHCO_3$ to the evolution flask, then add the acid directly to the flask, omitting the separatory funnel and the current of air. Boil the solution until about 50 cc. of distillate has passed over.

CALCULATIONS

The calculation of the component pigments of a mixed or combination pigment may be a somewhat difficult matter. Certain assumptions must be made, depending upon the complexity of the mixed pigment, as to the composition or formulas of component pigments and as to the manner in which the acidic and basic radicles are combined. Add any Al_2O_3 (Fe_2O_3) found in the soluble portion to the siliceous matter and report the sum as "Insoluble siliceous matter," unless the soluble Al is high; in this case, an aluminate is probably present, and the Al_2O_3 should be reported as Al_2O_3. If a small amount of soluble Mg is found, it should also be added to the siliceous matter. If the soluble Mg is high, the presence of $MgCO_3$ is indicated, and the MgO is calculated to $MgCO_3$ as pointed out below. The insoluble siliceous matter reported should be based on the weight obtained on drying the total insoluble matter at 105° C. if the combined H_2O contained therein is to be considered.

In the absence of ZnS or TiO_2, report $BaSO_4$ as $BaSO_4$. If ZnS is present, calculate the $BaSO_4$ equivalent by multiplying by 2.85; report sum of $ZnS+BaSO_4$ as "lithopone." If TiO_2 is present, calculate the $BaSO_4$ equivalent by multiplying by 3.17; report sum of TiO_2+BaSO_4 as "titanium pigment." Report residual $BaSO_4$ as $BaSO_4$. If TiO_2 is present and $BaSO_4$ is absent or is present in a smaller amount than would be indicated by the above factor, then report TiO_2 as TiO_2, and $BaSO_4$ as $BaSO_4$. If $CaCO_3$, $CaSO_4$, $BaCO_3$, and $MgCO_3$ are absent calculate CO_2 to basic carbonate white lead, $(PbCO_3)_2 \cdot Pb(OH)_2$, and soluble SO_3 to $PbSO_4$. Any excess of Pb is calculated to PbO, added to the $PbSO_4$, and the sum reported as basic lead sulfate; or, multiply the sum of $PbSO_4+PbO$ by 0.058 to obtain the ZnO; add this result to the $PbSO_4+PbO$ and report as basic sulfate white lead. (The ZnO factor is based on the assumption that the average composition of commercial basic sulfate white lead is: 78.5 per cent $PbSO_4$, 16.0 per cent PbO, and 5.5 per cent ZnO.) Lead oxide (PbO) should not be reported except in the presence of $PbSO_4$; unless the entire analysis is reported in the elementary or oxide form.

If the sample contains CO_2 but no soluble SO_3, calculate total Pb to basic carbonate white lead, $(PbCO_3)_2 \cdot Pb(OH)_2$; calculate residual CO_2 to $CaCO_3$, then to $BaCO_3$ and $MgCO_3$ if soluble Ba and Mg should be present in sufficient amounts to indicate the presence of these carbonates. The CO_2 result will be an index of this. A small amount of residual CaO is probably from the sliceous matter and should be added to the insoluble siliceous matter.

A small amount of soluble Ba may be from the $CaCO_3$ used or may be due to the solubility of $BaSO_4$ if this compound is present in the original pigment. This Ba may be calculated to $BaSO_4$ and added to the $BaSO_4$ found in the insoluble matter.

If the sample contains soluble SO_3 but no CO_2, calculate CaO to $CaSO_4$ or $CaSO_4 \cdot 2H_2O$; residual SO_3 to $PbSO_4$; add residual PbO to $PbSO_4$ and report sum as basic lead sulfate; or, multiply $PbSO_4+$

PbO by 0.058 and add the result to the $PbSO_4+PbO$, and report the total as basic sulfate white lead.

If the sample contains $CaCO_3$ ($MgCO_3$, $BaCO_3$) and also basic sulfate white lead, or $CaSO_4$ and basic carbonate white lead; or a mixture of these; it is not possible to determine or calculate the amount of $PbCO_3$ or $PbSO_4$ with any degree of certainty (Notes 3 and 5). The presence of appreciable amounts of CaO and SO_3 in the water-soluble matter indicates the probable presence of $CaSO_4$ in the original pigment. The following arbitrary calculations may be made; calculate water-soluble SO_3 to $CaSO_4$ or $CaSO_4 \cdot 2H_2O$, subtract this SO_3 from total soluble SO_3 and calculate the remainder to $PbSO_4$; calculate residual CaO to $CaCO_3$, and then residual CO_2 to $(PbCO_3)_2 \cdot Pb(OH)_2$. If there is an excess of CO_2, calculate to $MgCO_3$ or $BaCO_3$, if the amounts of soluble Mg and Ba indicate the probable presence of these carbonates. Add residual PbO to $PbSO_4$ and calculate, as above, to basic sulfate white lead. The procedure followed by the Federal Specifications Board should be noted.[1]

Report total antimony as Sb_2O_3.

Calculate sulfide sulfur to ZnS, subtract the Zn equivalent to the S from the total Zn, then subtract the Zn required for the basic sulfate white lead, and report the remainder as ZnO.

Report moisture, loss on ignition, SO_2, and matter soluble in water directly.

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[1] Federal Specifications Board Specification No. 10*b* for "White Paint and Tinted Paints Made on a White Base, Semipaste and Ready Mixed"; U. S. Bureau of Standards *Circular No. 89*, 3d Ed., p. 2: "The total lead dissolved by dilute acetic acid and hot acid, ammonium acetate, weighed as lead sulfate, and this weight multiplied by the factor 0.883 shall be considered white lead. (It is not possible to determine the amount of lead carbonate and lead sulfate when carbonates or sulfates of other metals, such as calcium, are present. Also neither basic lead carbonate nor basic lead sulfate are definite compounds. The factor to convert $PbSO_4$ to $(PbCO_3)_2Pb(OH)_2$ is 0.854, to convert $PbSO_4$ to $PbSO_4 \cdot PbO$ is 0.868, and to convert $PbSO_4$ to $(PbSO_4)_2 \cdot PbO$ is 0.913. The arbitrary factor used under this specification is the mean of the largest and smallest of these three factors.)"

TENTATIVE METHOD OF ROUTINE ANALYSIS
OF
DRY CUPROUS OXIDE[1]

Serial Designation: D 283 - 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1928.

DETERMINATION OF TOTAL COPPER

Total Copper. 1. Weigh accurately a dry sample of from 0.15 to 0.2 g. of the material, transfer it to a 250-cc. beaker, add 10 to 15 cc. of HCl (sp. gr. 1.19) and 1 to 2 cc. of HNO_3 (sp. gr. 1.42) and boil for several minutes. Add 10 cc. of H_2SO_4 (sp. gr. 1.84) and heat until copious fumes of sulfuric acid are evolved. Cool, add, cautiously with stirring, 50 cc. of cold water, and boil to dissolve the sulfates. Cool, filter off any insoluble matter (SiO_2, $PbSO_4$, etc.) and wash the filter and residue until free from copper, with a cold H_2SO_4 solution (1 to 2-per-cent), catching the filtrate and washings in a 250-cc. beaker, keeping the total volume of the solution down to about 150 cc. Place in the solution a piece of clean, pure sheet aluminum (zinc may also be used) free from iron and copper. The sheet aluminum is convenient to use in the form of a cylinder about 3.5 to 4 cm. in diameter by 3.5 to 4 cm. in height, with a small extending piece about 7 to 8 cm. in height as a means of removing the cylinder. Cover the beaker and heat to gentle boiling for about 30 minutes or until the copper is completely precipitated as a metallic sponge on the aluminum. Thoroughly wash the copper sponge from the aluminum into a 250-cc. beaker and carefully examine the aluminum sheet for any remaining particles of copper. Wash the copper sponge several times by decantation with hot water, filtering the wash water through a 9-cm. filter paper, but retaining the copper as completely as possible in the beaker. The filtrate and washings may be discarded or used for the determination of iron, if present. Add from 10 to 15 cc. of ferric chloride-hydrochloric acid solution (prepared by dissolving 250 g. of $FeCl_3 \cdot 6H_2O$ in

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[1] Criticisms of this Tentative Method are solicited and should be directed to Mr. R. L. Hallett, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 105 York St., Brooklyn, N. Y.

500 cc. of HCl (1:1)), on the filter paper, catching this in the beaker containing the copper sponge. The copper generally dissolves in a few minutes without the need of heating. Break up any large particles of the copper sponge with a stirring rod. When the copper is completely dissolved, wash the filter thoroughly with cold water and, finally, dilute the filtrate to about 200 cc. with cold water, add 5 cc. of syrupy phosphoric acid and titrate the cold solution at once with 0.1 *N* $KMnO_4$ solution. Run a blank on the reagents used, and calculate the final corrected figure to percentage of total copper (1 cc. of 0.1 *N* $KMnO_4$ is equivalent to 0.0032 g. Cu).

DETERMINATION OF CUPROUS OXIDE

Cuprous Oxide.

2. Weigh accurately a dry sample of 0.25 g. of the material, transfer to a 250-cc. glass-stoppered Erlenmeyer flask, add from 10 to 15 cc. of ferric chloride-hydrochloric acid solution (prepared by dissolving 250 g. of $FeCl_3 \cdot 6H_2O$ in 500 cc. of HCl (1:1)), and a few glass beads. Stopper the flask, and rotate gently until the cuprous oxide is completely dissolved (this generally takes place within a few minutes on high-grade, finely-ground samples). Warming gently on the steam bath accelerates solution, but much heating is not advisable, unless the solution is protected from oxidation. When the cuprous oxide is completely dissolved, add 200 cc. of cold water, 5 cc. of syrupy phosphoric acid, and titrate the cold solution at once with 0.1 *N* $KMnO_4$ solution. Run a blank on the reagents used, and calculate the final corrected figure to percentage of Cu_2O and report as such (1 cc. of 0.1 *N* $KMnO_4$ is equivalent to 0.0064 g. Cu or 0.0072 g. Cu_2O). Subtract the Cu equivalent of this result from the percentage of total Cu, as determined in Section 1, calculate the balance to cupric oxide (CuO), and report as percentage of CuO ($Cu \times 1.252 = CuO$).

NOTE.—Occasionally, samples of cuprous oxide (especially those of high purity) show some metallic copper. This is generally evident in a test for determination of coarse particles. Any metallic copper present in a sample is be included in the cuprous oxide determined.

TENTATIVE METHOD OF ROUTINE ANALYSIS
OF
DRY MERCURIC OXIDE[1]

Serial Designation: D 284 - 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1928.

DETERMINATION OF ALKALINITY OR ACIDITY

Alkalinity or Acidity. 1. Alkalinity or acidity shall be determined in accordance with the Tentative Method of Test for Alkalinity or Acidity of Pigments (Serial Designation: D 278 - 28 T) of the American Society for Testing Materials.[2]

DETERMINATION OF FREE MERCURY

Free Mercury. 2. Free mercury shall be determined by examining a representative sample of the dry mercuric oxide under a microscope for the presence of free mercury globules.

DETERMINATION OF COMBINED MERCURIC MERCURY

SOLUTIONS REQUIRED

Solutions Required. 3. (*a*) *Aqua Regia.*—Mix one volume of HNO_3 (sp. gr. 1.42) and three volumes of HCl (sp. gr. 1.19).

(*b*) *Ammonium Monosulfide.*—Prepare fresh by saturating three volumes of NH_4OH (sp. gr. 0.90) with H_2S, and then adding two volumes of NH_4OH (sp. gr. 0.90) to the saturated solution.

(*c*) *Ammonium Polysulfide.*—Dissolve 25 g. of "flowers of sulfur" in a mixture of 500 cc. of ammonium sulfide and 500 cc. of water.

PROCEDURE

(*a*) *In the absence of other metals precipitable as sulfides:*

Procedure. 4. Weigh accurately a dry sample of 0.5 g. of the material, transfer it to a 400-cc. beaker, add a solution of 40 cc. of water and 25 cc. of HCl (sp. gr. 1.19), and stir until all soluble matter has dissolved.

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[1] Criticisms of this Tentative Method are solicited and should be directed to Mr. R. L. Hallett, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 105 York St., Brooklyn, N. Y.

[2] See p. 877.

(Solution should be carried out as near room temperature as possible, since on boiling solutions of mercuric chloride some of the $HgCl_2$ may be volatilized.) Filter off any insoluble matter and wash with warm (not boiling) water until free of chlorides. If appreciable iron is present (otherwise omit this part of the procedure), add sulfurous acid solution in slight excess to the filtrate or original solution to reduce the ferric iron, and warm (do not boil) to expel the excess of sulfur dioxide. Neutralize the solution with NH_4OH, add 1 cc. of HCl (sp. gr. 1.19) and 300 cc. of water; pass H_2S through the cold solution until saturated, when the precipitate of HgS readily settles, leaving a clear supernatant liquid. Filter, without delay, on a weighed Gooch crucible, wash well (about six times) with cold distilled water and then three times with 10-cc. portions of cold 95-per-cent ethyl alcohol. Set the crucible in a small beaker, add sufficient carbon disulfide or carbon tetrachloride to cover the precipitate, cover the beaker with a watch-glass, and let stand for about 30 minutes. Lift the crucible out of the beaker, draining off the solvent, replace in the filtering tube and wash the precipitate with carbon tetrachloride until 1 cc. of the filtrate leaves no visible residue after evaporation. Wash with three 10-cc. portions of cold 95-per-cent ethyl alcohol and once with ethyl ether. Set the crucible on top of an oven until the ether has evaporated, then place it in the oven and dry to constant weight at from 105 to 110° C. Cool and weigh as mercuric sulfide (HgS); calculate the percentage of mercury (Hg) in the sample ($HgS \times 0.862 = Hg$).

(*b*) *In the presence of other metals precipitable as sulfides:*

Procedure.

5. Treat a dry sample of 0.5 g. of the material as described in Section 3 until the sulfides are precipitated and then filter on a small paper and wash with water containing a little H_2S. Transfer the paper and precipitate to a porcelain dish or casserole, spreading the paper out, cover with dilute HNO_3 (sp. gr. 1.2-1.3), cover with a watch-glass and boil several minutes. Dilute with water, filter on d small paper and wash with hot water containing a little HNO_3. Transfer the filter and precipitate to the porcelain dish or casserole, add a little aqua regia, heat gently until the HgS is dissolved and free chlorine expelled, filter off separated sulfur (and $PbSO_4$ if present), wash the residue with hot (not boiling) water until free from chlorides. Nearly neutralize[1] the filtrate with pure Na_2CO_3, add a slight excess of freshly-prepared colorless ammonium monosulfide, and then, with constant agitation, a solution of pure NaOH (free from Ag, Al_2O_3, and

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[1] J. Volhard, Liebig's *Ann.*, Vol. 255, p. 255 (1889). Treadwell-Hall, *Analytical Chemistry*, Vol. II, pp. 169, 194, 235 (1914).

SiO_2) until the dark liquid begins to lighten. Heat the solution to boiling and add more NaOH solution until the liquid is perfectly clear. The solution now contains the mercury as a thio-salt (Note). Add an excess of NH_4NO_3 and boil the solution until the ammonia is almost entirely expelled; let the precipitate settle, and decant the supernatant liquid through a weighed Gooch crucible. Wash the precipitate two or three times by decantation with water containing a little H_2S, then by decantation with hot water until the wash water no longer reacts with $AgNO_3$ solution. Transfer the precipitate to the crucible, wash with 95-per-cent ethyl alcohol, treat with carbon bisulfide or carbon tetrachloride, and finally weigh the HgS, as described in Section 3.

NOTE.—If some $PbSO_4$ should go into solution with the mercury on treating with aqua regia, it will be converted by the ammonium sulfide and NaOH into insoluble PbS, which should be filtered off and washed with dilute NaOH solution.

6. If the material contains arsenic, antimony or tin, treat a dry sample of 0.5 g. as described in Section 3 until the sulfides are precipitated, then filter on a small paper and wash with water containing a little H_2S. Transfer the precipitate to a porcelain dish or casserole, cover with ammonium polysulfide, and warm gently for several minutes, stirring constantly. Filter on a small paper and wash with hot water containing ammonium polysulfide. From this point treat the precipitate as described in Section 5 for the H_2S precipitate.

DETERMINATION OF ASH

Ash. 7. Ignite a dry sample of 2 g. of the material in a weighed porcelain crucible or dish under a well-ventilated hood (the fumes are poisonous). Cool and weigh the residue. Calculate the percentage of ash.

TENTATIVE METHOD OF TEST
FOR
THE DETERMINATION OF AUTOGENOUS IGNITION TEMPERATURES[1]

Serial Designation: D 286 - 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1928.

Scope. 1. This method is applicable to liquid and semi-liquid petroleum products.

APPARATUS

Solder Bath. 2. (*a*) *Solder Bath.*—The solder bath shall consist of a round-bottomed iron pot about $4\frac{1}{2}$ in. in diameter and $3\frac{1}{2}$ in. in height, and filled with alloy to within about 1 in. of the top.

NOTE.—The alloy should have a melting point below the ignition temperature of the product being tested. For products with relatively low ignition temperatures, an alloy of lead, tin and cadmium is advisable; for medium temperatures, a 50-per-cent tin-lead alloy; for high temperatures, lead.

Conical Flask. (*b*) *Conical Flask.*—The flask shall be of Pyrex glass in conical form with flat bottom, and shall be about $4\frac{1}{4}$ in. (11.4 cm.) in height, $2\frac{3}{8}$ in. (6.0 cm.) in diameter at the bottom and $1\frac{1}{8}$ in. (2.85 cm.) in diameter at the top. The capacity for these dimensions is about 160 cc. and the ratio of surface area to volume is about 1:1.

Gas Burner. (*c*) *Gas Burner.*—The gas burner for heating the bath may be of any ordinary form and shall be large enough to be capable of heating the bath to the desired temperature.

Temperature Measuring Device. (*d*) *Thermocouple or Thermometer.*—The temperature measuring device should be a calibrated thermocouple with a quartz protecting tube. A calibrated, high-temperature, nitrogen-filled thermometer may be substituted for the thermocouple, in which case appropriate corrections shall be applied.

Pipette. (*e*) *Pipette.*—The pipette shall be of a small capacity, readily adaptable to the delivery of drops.

PROCEDURE

Procedure. 3. The alloy in the solder bath shall be melted and the flask partially submerged in the molten alloy to a depth equal to two-thirds its height. It should be centered in the bath and shall not touch the walls of the iron pot at any point. The thermocouple (or thermometer) shall be placed and held firmly by suitable clips in the solder bath in such a position that its end shall be about ¼ in. from the bottom of the bath and ¼ in. from the side of the flask. The temperature of the bath shall be brought to and held at a temperature near the probable ignition temperature of the sample under test. Various amounts of the sample (1, 2, 3, 4, etc., drops from the pipette) shall be added successively to the flask, at least 1 minute being allowed to elapse after each addition and the gases and vapors completely displaced after each addition of the sample by the aid of a slow stream of air or a hand bulb with a bent (right-angle) delivery tube. If ignition takes place when one of the charges is added, the temperature should be lowered about 5° C. and the process repeated, starting with the number of drops that ignited in the first instance, and using other volumes if necessary. The operator should proceed, in general, in this manner, raising or lowering the temperature by approximately 5° C. intervals, according as ignition does not or does take place, holding each temperature approximately constant during all trials at that temperature, until an indicated temperature is found at which ignition invariably takes place, but at 5° C. below which ignition fails to take place. The minimum indicated ignition temperature may then be determined by repeated trials between the indicated temperature and a temperature 5° C. less. Results should be duplicable to within ± 2° C. of the indicated temperature. It is advisable in some of the various trials, especially where the large numbers of drops of the sample are added, to introduce a little additional air into the flask by means of the rubber bulb and bent delivery tube.

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[1] Criticisms of this Tentative Method are solicited and should be directed to Mr. R. P. Anderson, Secretary of Committee D-2 on Petroleum Products and Lubricants, 250 Park Ave., New York City.

TENTATIVE METHOD OF TEST
FOR
DISTILLATION OF CRUDE PETROLEUM[1]

Serial Designation: D 285 - 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1928.

Scope. 1. This method is intended for determining the percentages and distillation range of the naphtha in any crude oil of the class commercially known as refinable crudes. This method does not attempt to specify what quality of product shall be defined as naphtha nor can it be expected to duplicate the results of commercial refining operations. It defines apparatus and procedure, leaving selection of numerical limits and interpretation of results to be agreed upon by the interested parties.

APPARATUS

Flask. 2. *Flask.*—The distillation flask shall be a 300-cc. Hempel distilling flask, Fig. 1, the dimensions and allowable tolerances being as follows:

			TOLERANCES	
	CENTIMETERS	INCHES	CENTIMETERS	INCHES
Diameter of bulb, outside	10.2	4.0	±0.2	±0.08
Diameter of neck, outside	2.9	1.125	±0.1	±0.04
Length of neck	25.4	10.0	±0.4	±0.16
Distance, top of neck to center of vapor tube	6.4	2.5	±0.3	±0.12
Length of vapor tube	17.2	6.75	±0.5	±0.20
Diameter of vapor tube, outside	0.8	0.3125	±0.1	±0.04

The vapor tube shall be set at an angle of 80 deg. with the neck of the flask, subject to a permissible variation of plus or minus 5 deg.

Fractionating Column. 3. *Fractionating Column.*—The fractionating column (see *a*, Fig. 2) shall be made of a length of No. 18 iron jack chain, enough to pack under its own weight into a column 2.54 cm. (1 in.) in diameter and 17.51 cm. (6½ in.) in length. It may conveniently be "strung" on a loop of wire so that it hangs in loops about 2 ft. in length, which makes the chain more convenient to handle than when it is not looped together. The device used for supporting the column (see *b*, Fig. 2) shall be made of a suitable length of wire, preferably, though not necessarily of nickel-chromium, about No. 18 gage. One end shall be wound in a spiral a little less than 1 in. in diameter, and the remaining wire shall be bent at right angles to the plane of the spiral and cut off at a length of about 9½ in. A small loop shall be bent into the end away from the spiral and put through a hole drilled in a strip of spring steel (see *c*, Fig. 2) or other suitable material about 0.015 in. in thick-

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[1] Criticisms of this Tentative Method are solicited and should be directed to Mr. R. P. Anderson. Secretary of Committee D-2 on Petroleum Products and Lubricants, 250 Park Ave., New York City.

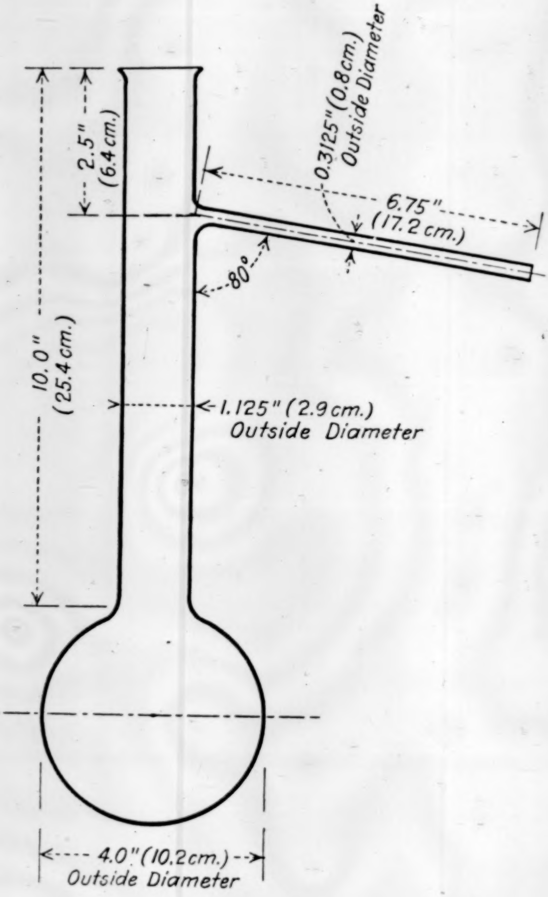
0.3125" (0.8 cm.)
Outside Diameter
2.5"
(6.4 cm.)
6.75"
(17.2 cm.)
80°
10.0"
(25.4 cm.)
1.125" (2.9 cm.)
Outside Diameter
4.0" (10.2 cm.)
Outside Diameter

FIG. 1.—Dimensions of a 300-cc. Hempel Flask.

ness, $\frac{3}{8}$ in. in width, and 3 in. in length, bent around a cylinder 1 in. in diameter. When allowed to expand this spring strip should hold firmly on the inside of the neck of the flask and provide a secure support for the column of chain.

Thermometer.

4. *Thermometer.*—The A.S.T.M. Low-Distillation Thermometer, conforming to the requirements specified in Section 6 of the Standard Method of Test for Distillation of Natural Gas Gasoline (Serial Designation: D 216) of the American Society for Testing Materials[1] shall be used.

Condenser.

5. *Condenser.*—The condenser shall consist of a $\frac{9}{16}$-in. (14.29-mm.) OD No. 20 Stubbs Gage seamless brass tube, 22 in. (55.88 cm.) in length. It shall be set at an angle of 80 deg. from the perpendicular and surrounded with a cooling bath 15 in. (38.1 cm.) in length, approximately 4 in. (10.16 cm.) in width, by 6 in. (15.24 cm.) in height. The lower end of the condenser tube shall be cut off at an acute angle, and curved downward for a length of 3 in. (7.62 cm.) and slightly backward to insure contact with the wall of the graduate 1 to $1\frac{1}{4}$ in. (2.54 to 3.18 cm.) below the top of the graduate when it is in position to receive the distillate.

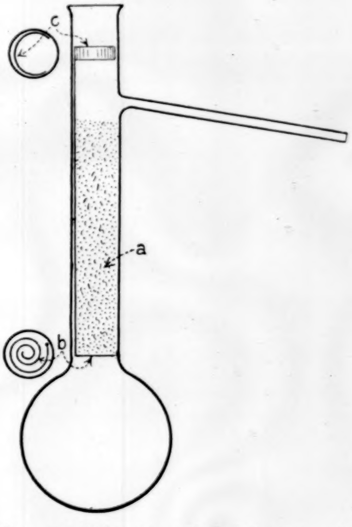

FIG. 2.—Fractionating Column and Supporting Device in a Hempel Flask.

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 387.

Shield and Support.

6. *Shield and Support.*[1]—The shield shall be of any convenient type having a minimum horizontal dimension of 6 in. The flask shall rest on a board of ¼-in. (0.64-cm.) transite or hard asbestos, in the center of which is cut a hole 3½ in. (8.9 cm.) in diameter. The board shall not be less than 6 in. (15.24 cm.) in width and shall be supported by an ordinary ring stand and ring.

7. *Gas Burner or Electric Heater:*

Gas Burner.

(*a*) *Gas Burner.*—The burner shall be so constructed that sufficient heat can be obtained to distill the product at the uniform rate specified below. The flame should never be so large that it spreads over a circle of a diameter greater than 5 in. (12.7 cm.) on the under surface of the asbestos board. A sensitive regulating valve is a necessary adjunct, as it gives complete control of heating.

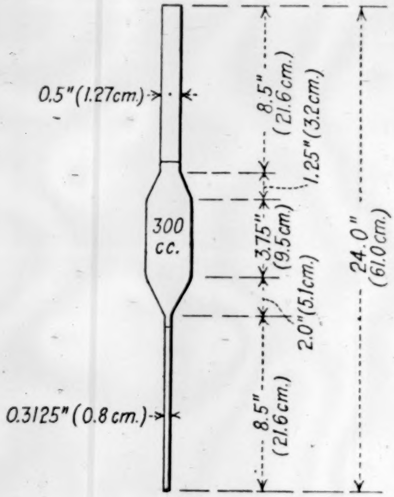

FIG. 3.—Measuring Pipette.

Electric Heater.

(*b*) *Electric Heater.*—The electric heater, which may be used in place of the gas flame, shall be capable of maintaining the distillation at the rate specified in Section 9 (*i*). The electric heater shall be fitted with an asbestos board top ⅛ to ¼ in. (3.18 to 6.35 mm.) in thickness having a hole 3½ in. (8.9 cm.) in diameter in the center. When an electric heater is employed the portion of the shield above the asbestos board shall be the same as with the gas burner, but the part below the board may be omitted.

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[1] An illustration of the condenser and of a suitable shield and support are shown in Fig. 2 of the Standard Method of Test for Distillation of Gasoline, Naphtha, Kerosine and Similar Petroleum Products (Serial Designation: D 86) of the American Society for Testing Materials. 1927 Book of A.S.T.M. Standards, Part II, p. 378.

Graduates and Pipettes.

8. *Measuring Graduates and Pipettes.*—Filling charges and distillation fractions shall be measured with suitable accurate graduated cylinders or other volumetric glassware. A special 300-cc. pipette, Fig. 3, is a convenient device for measuring charges, but an accurate graduate may be used if desired. The regular 100-cc. graduate used in gasoline distillations as specified in Section 7 of the Standard Method of Test for Distillation of Gasoline, Naphtha, Kerosine and Similar Petroleum Products (Serial Designation: D 86) of the American Society for Testing Materials[1] is reasonably satisfactory for measuring distillation fractions, but a graduate of similar dimensions that can be tightly stoppered is preferable. One can be made by cutting down a standard graduate to remove the lip and then fire polishing.

PROCEDURE

Procedure.

9. (*a*) The condenser bath shall be filled with cracked ice and sodium chloride or calcium chloride to form a freezing mixture that will cover the condenser tube and maintain a temperature between 0 and 10° F.

(*b*) The condenser tube shall be swabbed or cleaned inside to remove any liquid remaining from a previous test.

(*c*) The specific gravity of the oil to be tested shall first be determined in accordance with the Tentative Method of Test for Gravity of Petroleum and Petroleum Products by Means of the Hydrometer (Serial Designation: D 287 – 28 T) of the American Society for Testing Materials.[2]

(*d*) A 300-cc. sample of the oil[3] shall be measured into the Hempel flask by any suitable means. For less viscous oils a pipette or graduate may be used. If the oil is decidedly viscous a sample equivalent to 300-cc. at 60° F. shall be weighed into the flask. None of the liquid shall be permitted to flow into the vapor tube.

The weight in grams of the 300-cc. sample shall then be calculated. (The weight in grams of 300 cc. of oil is equivalent to 300 times its specific gravity determined in accordance with Paragraph (*c*).)

(*e*) The supporting device for the fractionating column, Fig. 2, shall be put in place and the proper quantity of iron chain dropped in carefully so that it fills the space uniformly and without channels. Tapping the flask while the iron chain is being added is helpful, but the column shall not be compressed after all the chain is in place.

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 378.

[2] See p. 924.

[3] In case water in the crude oil causes bumping, the sample shall be dehydrated by some suitable method, without loss of naphtha, before making the determination.

(*f*) The thermometer, provided with a cork, shall be fitted tightly into the flask, so that it will be in the middle of the neck and so that the lower end of the capillary tube is about $\frac{1}{16}$ in. below the level of the inside of the bottom of the vapor tube at its junction with the neck of the flask.

(*g*) The charged flask shall be placed in position on the hard asbestos board, used with the gas burner or the electric heater and connected to the condenser with a carefully fitted cork through which the vapor tube passes. The position of the flask shall be adjusted so that the vapor tube extends into the condenser tube not less than 1 in. (2.54 cm.) nor more than 2 in. (5.08 cm.)

(*h*) A clean, dry, graduated cylinder shall be placed at the outlet of the condenser tube in such a position that the condenser tube shall extend at least 1 in. into the graduate. The graduate shall be immersed up to the level of about 1 in. below the top of the condenser tube in a transparent container of water maintained at a temperature of from 32 to 40° F. (0 to 4.4° C.). During the distillation, the top of the graduate shall be covered closely with a piece of blotting paper or its equivalent, cut to fit the condenser tube tightly.

(*i*) When everything is in readiness, heat shall be applied. The fractionating column causes some little delay between the time when the liquid starts to boil and the time the vapor enters the condenser. It is, therefore permissible to apply heat vigorously until the liquid begins to boil, then to slow down the application of heat so that the distillate begins to come over at a moderate rate. For the first 5 to 10 cc. distilled the rate shall be from 2 to 3 cc. per minute; thereafter, the rate of distillation shall be increased to from 4 to 5 cc. per minute.

Distillation. (*j*) When the thermometer reads ....[1] the graduate shall be withdrawn from beneath the condenser and the distillation discontinued. The graduate shall be tightly stoppered and allowed to stand until all sediment and moisture have settled out and until its contents have reached a temperature between 55 and 65° F. The total volume in the graduate shall then be read and recorded as D. The volume of water, if any, shall be read and recorded as W.

The percentage of naphtha in the crude oil shall be calculated from the following formula:

$$\text{Percentage of naphtha} = \frac{D - W}{300 - W} \times 100$$

The whole procedure shall be repeated enough times to yield a total volume of distillate of not less than 100 cc.

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[1] The temperature at which the distillation shall be stopped can best be decided by mutual agreement between the parties concerned in the evaluation of a given crude petroleum.

Naphtha Distillation.

10. *Naphtha Distillation.*—The distillates shall be poured together (taking care to avoid losses by evaporation and rejecting the layers of water, if present) and shall be mixed thoroughly by shaking. A distillation test of the combined distillates shall be made in accordance with the Standard Method of Test for Distillation of Gasoline, Naphtha, Kerosine and Similar Petroleum Products (Serial Designation: D 86) of the American Society for Testing Materials,[1] except that the initial boiling point shall be recorded and the volume of distillate collected in the cylinder shall be observed and recorded to the nearest 0.5 cc. when the mercury of the thermometer reaches 212° F. (100° C.), 221° F. (105° C.), 284° F. (140° C.), 392° F. (200° C.) and the end point.

ACCURACY

Accuracy.

11. Results of duplicate tests in the crude-oil distillation should not differ from each other by more than 0.5 per cent. In the naphtha distillation duplicate results obtained for initial boiling point and maximum temperature, respectively, shall not differ from each other by more than 6° F. (3.33° C.). Duplicate readings of the volume of distillate collected in the cylinder when each of the prescribed temperature points is reached should not differ by more than 2 cc.

CORRECTION FOR BAROMETRIC PRESSURE

Correction.

12. The actual barometric pressure shall be ascertained and recorded, but no correction shall be made except in case of dispute, when the temperature points shall be corrected to 760 mm. (29.92 in.) by the use of the Sydney Young Equation, as follows:

For Centigrade Readings:

$$C_c = 0.00012\,(760 - P)(273 + t_c)$$

For Fahrenheit Readings:

$$C_f = 0.00012\,(760 - P)(460 + t_f),$$

in which C_c and C_f are, respectively, corrections to be added to the observed temperature t_c or t_f; and P is the barometric pressure in millimeters of mercury.

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 378.

TENTATIVE METHOD OF TEST

FOR

GRAVITY OF PETROLEUM AND PETROLEUM PRODUCTS BY MEANS OF THE HYDROMETER[1]

Serial Designation: D 287 - 28 T

This is a Tentative Standard, published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1928.

Scope. 1. This method covers the determination of the specific gravity or the A.P.I. gravity of crude petroleum and petroleum products normally handled as liquids. The determination of the gravity of mixtures of petroleum products with other substances is treated as a special case owing to the fact that the coefficients of expansion of such mixtures may not be the same as those of petroleum or its products. The determination of the specific gravity of road oils, road tars, asphalt cements and soft tar pitches is covered by the Standard Method of Test for Specific Gravity of Road Oils, Road Tars, Asphalt Cements and Soft Tar Pitches (Serial Designation: D 70) of the American Society for Testing Materials[2] and the testing of these products is, therefore, specifically excluded from the scope of this method.

DEFINITIONS

Specific Gravity. 2. (*a*) *Specific Gravity.*—The specific gravity of a petroleum oil and of mixtures of petroleum products with other substances is the ratio of the weight of a given volume of the material at a temperature of 60° F. (15.56° C.) to the weight of an equal volume of distilled water at the same temperature, both weights being corrected for the buoyancy of air.

A. P. I. Gravity. (*b*) *A.P.I. Gravity.*—The A.P.I. gravity scale is an arbitrary one which is related to the specific gravity of a petroleum oil in accordance with the formula:

$$\text{Degrees A. P. I.} = \frac{141.5}{\text{sp. gr. } 60°/60° \text{ F.}} - 131.5$$

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[1] Criticisms of this Tentative Method are solicited and should be directed to Mr. R. P. Anderson, Secretary of Committee D-2 on Petroleum Products and Lubricants, 250 Park Ave., New York City.

[2] 1927 Book of A.S.T.M. Standards, Part II, p. 510.

A table showing the equivalent specific gravity, pounds per gallon and gallons per pound at 60° F. for each degree A.P.I. from 0 to 100° A.P.I. is given in the Appendix to this method.

APPARATUS

There are two kinds of hydrometers in common use, the plain type and the combined thermometer and hydrometer, known as a thermo-hydrometer. Although the thermo-hydrometer type of instrument is sufficiently satisfactory for routine use, the thermometer incorporated in it possesses certain inherent defects of design which render it unfit for use when results of unquestioned accuracy are desired. Therefore, in all referee tests the temperature of the sample being tested must be determined by means of a separate thermometer.

Hydrometer Calibrations.

3. *Hydrometer Calibrations.*—The hydrometer may be calibrated either in terms of specific gravity or degrees A.P.I. It shall be of glass of the conventional constant mass and variable displacement type, with a paper hand-written scale. The range may be any suitable portion of the interval between 0 and 100° A.P.I. (1.0760 to 0.6112 sp. gr.) and it shall be so divided that 0.1° A.P.I. or 0.0005 of a unit of specific gravity shall not be less than 1 mm. (0.039 in.) in width. The value of the smallest sub-divisions shall be 0.1° A.P.I. when the instrument is calibrated in degrees A.P.I. or 0.0005 of a unit of specific gravity when it is calibrated in the specific gravity scale. The accuracy of calibration of the hydrometer shall be such that the error at any point of the scale shall not exceed the value of one smallest scale division. Each fifth smallest sub-division on the scale shall be denoted by a longer line. The graduations shall be numbered at each multiple of 1° A.P.I. or at each multiple of 0.01 of a unit of specific gravity, in accordance with the type of calibration used. The paper scale, or an extension thereof, of the hydrometer shall have plainly printed on it the name of the manufacturer, a serial number and the definition of the scale.

NOTE.—In the case of A.P.I. hydrometers the scale is defined by the expression:

$$\text{``Degrees A.P.I.} = \frac{141.5}{\text{sp. gr. } 60°/60° \text{ F.}} - 131.5\text{''}$$

In the case of specific gravity hydrometers the inscription "Sp. gr. 60°/60° F., Petroleum" is sufficient to denote that the hydrometer is intended to determine specific gravities at 60° F. relative to water at 60° F. when the readings are taken at 60° F.

The long axis of the hydrometer shall assume a vertical position when the instrument is floating freely in the sample. Any solid material, such as shot, paper, etc., used in the weighting of the hydrometer shall be firmly secured in place by the use of a suitable cement, the softening point of which lies well above 195° F. When mercury is used for weighting, it shall be placed in a small bulb below the main bulb of the hydrometer and completely separated from the bulb by means of a glass partition.

Thermometers.

4. (*a*) *Separate Thermometer.*—These specifications cover a total immersion thermometer graduated in either Centigrade or Fahrenheit degrees as specified, the ranges being −20 to +102° C. or −5 to +215° F., respectively.

TYPE: Etched stem, glass.

LIQUID: Mercury.

RANGE AND SUBDIVISION: −20 to +102° C. in 0.2° C. or −5 to +215° F. in 0.5° F.

TOTAL LENGTH: 403 to 409 mm. (15.87 to 16.10 in.).

STEM: Plain front, enamel back, suitable thermometer tubing.
Diameter 7 to 8 mm. (0.276 to 0.315 in.).

BULB: Corning normal or equally suitable thermometer glass, heavy wall.
Length 14 to 19 mm. (0.55 to 0.75 in.).
Diameter 6 to 7 mm. (0.236 to 0.275 in.).

DISTANCE TO −20° C. or −5° F. LINE FROM BOTTOM OF BULB: 32 to 51 mm. (1.26 to 2.00 in.).

DISTANCE TO +102° C. or +215° F. LINE FROM TOP OF STEM: 25 to 45 mm. (0.98 to 1.77 in.)

FILLING ABOVE MERCURY: Nitrogen gas.

TOP FINISH: Glass ring.

GRADUATIONS: All lines, figures and letters clear cut and distinct. Each whole degree Centigrade or Fahrenheit line to be longer than the remaining lines. Graduations to be numbered at each multiple of 2° C. or 5° F.

IMMERSION: Total.

SPECIAL MARKING: "A.S.T.M. gr.," a serial number and the manufacturer's name or trade mark shall be etched on the stem.

SCALE ERROR: The error at any point of the scale when the thermometer is standardized as provided below shall not exceed 0.1° C. or 0.25° F.

STANDARDIZATION: The thermometer shall be standardized immersed in the testing bath to the top of the mercury column, at the ice point and at temperature intervals of from 15 to 20° C. or 30 to 40° F.

CASE: The thermometer shall be supplied in a suitable case on which shall appear the marking: "A.S.T.M. gr. −20 to +102° C." or "A.S.T.M. gr. −5 to +215° F." according to the type of thermometer.

NOTE.—For the purpose of interpreting these specifications the following definitions apply:

The total length is the over-all length of the finished instrument.

The diameter is that measured with a ring gage.

The length of the bulb is the distance from the bottom of the bulb to the beginning of the enamel backing.

The top of the thermometer is the top of the finished instrument.

(*b*) *Thermometer for Thermo-hydrometer.*—The thermometer incorporated in the thermo-hydrometer type of instrument shall be of the paper scale type (scale to be placed in either the bulb or stem of the hydrometer) having a range of from 20 to 130° F. or 60 to 220° F.

depending upon the range of the hydrometer. The paper scale shall be graduated in 2° F. divisions accurate to ±1° F. (Note) and shall be printed in red ink to avoid any possibility of its being confused with the black gravity scale.

NOTE.—This approximates the limit of accuracy which it is possible to obtain in this type of thermometer. It becomes at once obvious, therefore, in view of the following facts, that a high degree of accuracy in the determination of the gravity of an oil can not be expected when this type of thermometer is used for the determination of the temperature of the sample undergoing test.

Between 10 and 11° A.P.I., one degree A.P.I. is equivalent to 0.0070 of a unit of specific gravity. Between 90 and 91° A.P.I., one degree A.P.I. is equivalent to only 0.0028 of a unit of specific gravity. In correcting the observed gravity of an oil of 10° A.P.I. for temperature, an error of ±2° F. in the determination of the temperature of the oil will introduce maximum error of only 0.1° A.P.I. (0.0007 sp. gr.) in the gravity. In correcting the observed gravity of an oil of 90° A.P.I. for temperature, an error of 1° F. in the determination of the temperature of the oil will introduce a maximum error of 0.3° A.P.I. (0.00084 sp. gr.) in the gravity. For convenience, the following table is given which shows the errors at each tenth degree A.P.I. from 10 to 100° A.P.I. which may be introduced into a corrected gravity as the result of an error of ±1° F. in the determination of the observed temperature:

OBSERVED GRAVITY, DEG. A.P.I.	RESULTANT MAXIMUM ERROR IN CORRECTED GRAVITY, DEG. A. P. I. PER ± 1° F. ERROR IN OBSERVED TEMPERATURE.
10–11	0.1
20–21	0.1
30–31	0.1
40–41	0.1
50–51	0.2
60–61	0.2
70–71	0.2
80–81	0.2
90–91	0.3
At 99	0.3

Hydrometer Cylinder.

5. *Hydrometer Cylinder.*—The hydrometer cylinder in which the sample for the gravity test is confined shall be made of clear glass and shall be cylindrical in shape. For convenience in pouring it may have a lip on the rim. The inside diameter of the cylinder shall be at least 2.54 cm. (1.0 in.) greater than the outside diameter of the hydrometer used in it. The height of the cylinder shall be such that the length of the column of sample it contains is greater by at least 2.54 cm. (1.0 in.) than the portion of the hydrometer which is immersed beneath the surface of the sample after a state of equilibrium has been reached.

PROCEDURE

Petroleum and Petroleum Products.

6. (*a*) The determination of the gravity of crude petroleum or its products may be made at any suitable temperature between 0 and

195° F. in accordance with the procedure described in Section 7. The observed gravity at the observed temperature shall be corrected to the gravity at 60° F. as described in Section 8.

Mixtures of Petroleum with Other Substances.

(*b*) The gravity of mixtures of petroleum products with other substances shall be determined at a temperature of 60° F. in accordance with the procedure described in Section 7, since there are no nationally recognized tables giving the coefficients of expansion of such mixtures.

Procedure.

7. The sample to be tested for gravity shall be poured into the clean hydrometer cylinder without splashing, so as to avoid the formation of air bubbles and to reduce to a minimum the evaporation of the lower boiling constituents of the lighter oils. If air bubbles are formed they shall be removed after they have collected on the surface, by touching them with a piece of clean blotting paper or filter paper before the hydrometer is placed in the sample. If the sample to be tested is easily volatile both the hydrometer and hydrometer cylinder shall be cooled before use to a temperature below that of the sample.

The cylinder containing the prepared sample shall be placed in a vertical position in a place free from air currents. The hydrometer shall be carefully lowered into the sample to a level two smallest scale divisions below that at which it will float and shall then be released. When the hydrometer has come to rest, floating freely away from the walls of the cylinder, the gravity shall be read as the point at which the surface of the sample apparently cuts the hydrometer scale. In the case of samples sufficiently transparent this point shall be determined by placing the eye slightly below the level of the liquid and slowly raising it until the surface of the sample first seen as a distorted ellipse seems to become a straight line cutting the hydrometer scale. In the case of non-transparent samples where this procedure cannot be followed, the point on the hydrometer scale to which the sample rises above the main surface of the liquid shall be read with the eye placed slightly above the plane of the surface of the sample. This reading shall then be corrected by subtracting in the case of A.P.I. hydrometers or adding in the case of specific-gravity hydrometers, an amount equal to the height which the sample rises on the hydrometer stem above the main liquid surface. This height will vary for different oils and different hydrometers and the amount of correction necessary will depend upon the width of the hydrometer scale graduations. The necessary correction factor shall be determined, therefore, for the particular hydrometer in use by observing the height above the main surface of the liquid to which the oil rises on the hydrometer scale when the hydrometer in question is immersed in a transparent oil having a surface tension similar to that of the sample under test.

The temperature of the sample shall be determined from the reading of the separate thermometer placed in the sample or from that of the thermometer contained in the hydrometer when the thermo-hydrometer type of instrument is used (see Note).

NOTE.—Precautions should, of course, be taken to prevent the temperature of the sample from changing appreciably during the time necessary to complete the test. This may be done when testing non-viscous oils by choosing a temperature of test only slightly different from the room temperature. When testing viscous oils which must be heated before testing it will be necessary to surround the test cylinder with a bath maintained at a constant desired temperature during the time of test.

Although it is usually satisfactory to determine the temperature of the sample immediately after reading the hydrometer, it is recommended that in all referee tests this temperature be determined both before and after the hydrometer is read.

CALCULATION

Calculation.

8. In the case of crude petroleum and petroleum products the determinations made in Section 7 are commonly referred to as "observed gravity and observed temperature." These observations shall be corrected to the gravity at 60° F. by the use of Tables 1 and 3 of the "National Standard Petroleum Oil Tables" as published in the U. S. Bureau of Standards *Circular No. 154*. Table 1 shall be employed if the observed gravity is in degrees A.P.I. and Table 3 if expressed as specific gravity.

Interpolations in Table 1 shall be made as follows: When the observed gravity ends in 1, 2, 3, 4 or 5 tenths of a degree A.P.I., find the degrees A.P.I. at 60° F. corresponding to the observed gravity, disregarding the tenths of a degree. To this value add tenths of a degree dropped from the observed gravity to obtain the corrected value of the gravity in degrees A.P.I. at 60° F. When the observed gravity ends in 6, 7, 8 or 9 tenths find the degrees A.P.I. at 60° F. corresponding to the next larger value of observed gravity in the table. Correct this figure by subtracting a number of tenths equal to the difference between the observed value and the next larger value.

ACCURACY

Duplicate Determinations.

9. Duplicate determinations shall agree within 0.1° A.P.I. or the equivalent thereof in units of specific gravity at the particular gravity being determined when the same hydrometer and thermometer are used in the tests.

Separate laboratories using different hydrometers and thermometers should obtain duplicate results agreeing within 0.5° A.P.I. or the equivalent thereof in units of specific gravity at the particular gravity being determined.

APPENDIX

The following table is primarily an abridgement of Table 5 of the "National Standard Petroleum Oil Tables" as published in the U. S. Bureau of Standards *Circular No. 154,* which contains similar data for each 0.1° A.P.I. from 10 to 100° A.P.I., inclusive. The data for gravities from 0 to 9° A.P.I., inclusive, have been added in order to extend the use of the A.P.I. gravity scale to petroleum oils having a specific gravity slightly greater than unity.

TABLE SHOWING SPECIFIC GRAVITIES, POUNDS PER GALLON, AND GALLONS PER POUND AT 60° F., CORRESPONDING TO DEGREES A.P.I.

Degrees A. P. I.	Specific Gravity at 60°/60° F.	Pounds per Gallon at 60° F.[1]	Gallons per Pound at 60° F.[1]	Degrees A. P. I.	Specific Gravity at 60°/60° F.	Pounds per Gallon at 60° F.[1]	Gallons per Pound at 60° F.[1]
0	1.0760	8.962	0.1116	50	0.7796	6.490	0.1541
1	1.0679	8.895	0.1124	51	0.7753	6.455	0.1549
2	1.0599	8.828	0.1133	52	0.7711	6.420	0.1558
3	1.0520	8.762	0.1141	53	0.7669	6.385	0.1566
4	1.0443	8.698	0.1150	54	0.7628	6.350	0.1575
5	1.0366	8.634	0.1158	55	0.7587	6.316	0.1583
6	1.0291	8.571	0.1167	56	0.7547	6.283	0.1592
7	1.0217	8.509	0.1175	57	0.7507	6.249	0.1600
8	1.0143	8.448	0.1184	58	0.7467	6.216	0.1609
9	1.0071	8.388	0.1192	59	0.7428	6.184	0.1617
10	1.0000	8.328	0.1201	60	0.7389	6.151	0.1626
11	0.9930	8.270	0.1209	61	0.7351	6.119	0.1634
12	0.9861	8.212	0.1218	62	0.7313	6.087	0.1643
13	0.9792	8.155	0.1226	63	0.7275	6.056	0.1651
14	0.9725	8.099	0.1235	64	0.7238	6.025	0.1660
15	0.9659	8.044	0.1243	65	0.7201	5.994	0.1668
16	0.9593	7.989	0.1252	66	0.7165	5.964	0.1677
17	0.9529	7.935	0.1260	67	0.7128	5.934	0.1685
18	0.9465	7.882	0.1269	68	0.7093	5.904	0.1694
19	0.9402	7.830	0.1277	69	0.7057	5.874	0.1702
20	0.9340	7.778	0.1286	70	0.7022	5.845	0.1711
21	0.9279	7.727	0.1294	71	0.6988	5.817	0.1719
22	0.9218	7.676	0.1303	72	0.6953	5.788	0.1728
23	0.9159	7.627	0.1311	73	0.6919	5.759	0.1736
24	0.9100	7.578	0.1320	74	0.6886	5.731	0.1745
25	0.9042	7.529	0.1328	75	0.6852	5.703	0.1753
26	0.8984	7.481	0.1337	76	0.6819	5.676	0.1762
27	0.8927	7.434	0.1345	77	0.6787	5.649	0.1770
28	0.8871	7.387	0.1354	78	0.6754	5.622	0.1779
29	0.8816	7.341	0.1362	79	0.6722	5.595	0.1787
30	0.8762	7.296	0.1371	80	0.6690	5.568	0.1796
31	0.8708	7.251	0.1379	81	0.6659	5.542	0.1804
32	0.8654	7.206	0.1388	82	0.6628	5.516	0.1813
33	0.8602	7.163	0.1396	83	0.6597	5.491	0.1821
34	0.8550	7.119	0.1405	84	0.6566	5.465	0.1830
35	0.8498	7.076	0.1413	85	0.6536	5.440	0.1838
36	0.8448	7.034	0.1422	86	0.6506	5.415	0.1847
37	0.8398	6.993	0.1430	87	0.6476	5.390	0.1855
38	0.8348	6.951	0.1439	88	0.6446	5.365	0.1864
39	0.8299	6.910	0.1447	89	0.6417	5.341	0.1872
40	0.8251	6.870	0.1456	90	0.6388	5.316	0.1881
41	0.8203	6.830	0.1464	91	0.6360	5.293	0.1889
42	0.8155	6.790	0.1473	92	0.6331	5.269	0.1898
43	0.8109	6.752	0.1481	93	0.6303	5.246	0.1906
44	0.8063	6.713	0.1490	94	0.6275	5.222	0.1915
45	0.8017	6.675	0.1498	95	0.6247	5.199	0.1924
46	0.7972	6.637	0.1507	96	0.6220	5.176	0.1932
47	0.7927	6.600	0.1515	97	0.6193	5.154	0.1940
48	0.7883	6.563	0.1524	98	0.6166	5.131	0.1949
49	0.7839	6.526	0.1532	99	0.6139	5.109	0.1957
				100	0.6112	5.086	0.1966

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[1] The data in this column are based upon apparent weights in air, the weight of one gallon of water at 60° F. in air being assumed to be 8.32828 lb. Consequently, a correction for the buoyancy of air is required in computing these figures from the specific gravities in the second column.

TENTATIVE METHOD OF TEST
FOR
MELTING POINT OF PETROLATUM[1]

Serial Designation: D 127 - 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestion, and as such is subject to annual revision.

ISSUED, 1922; REVISED, 1924, 1928.

DEFINITION

Definition. 1. *A.S.T.M. Petrolatum Melting Point.*—The temperature at which petrolatum becomes sufficiently fluid to drop from the thermometer used in making the determination under definite prescribed conditions.

APPARATUS

Thermometers. 2. (*a*) The melting point thermometer shall conform to the specifications for the A.S.T.M. paraffin wax melting point thermometer, as specified in Section 6 of the Standard Method of Test for Melting Point of Paraffin Wax (Serial Designation: D 87) of the American Society for Testing Materials.[2]

(*b*) The bath thermometer shall be of any suitable type accurate throughout the required range to 2° F.

Test Tubes. 3. The test tubes shall be 25 by 100 mm. in size, and shall be supplied with corks grooved at sides to permit air circulation and bored at the exact center to receive the thermometer.

Beakers. 4. The beakers shall be of the tall form type and have a capacity of 600 cc.

PROCEDURE

Procedure. 5. (*a*) Samples of sufficient size that exactly represent the petrolatum under inspection shall be secured. The material shall be melted slowly in a casserole or other suitable dish with stirring until the temperature reaches 180° F. A fresh portion of the sample shall be used for each determination. The source of heat shall then be removed and the petrolatum allowed to cool to 15° F. above the temperature that it is anticipated will be its melting point. The thermometer bulb shall be chilled to 40° F., wiped dry and while still cold thrust into the melted petrolatum so that approximately the lower half is submerged. It shall be withdrawn immediately, held vertically away from the heat until the surface dulls, and then placed in a water bath having a temperature not over 60° F. for five minutes.

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[1] Criticisms of this Tentative Method are solicited and should be directed to Mr. R. P. Anderson, Secretary of Committee D-2 on Petroleum Products and Lubricants, 250 Park Ave., New York City.

[2] 1927 Book of A.S.T.M. Standards, Part II, p. 409.

(*b*) The thermometer shall be securely fixed in a test tube by means of a cork so that the lowest point is 15 mm. above the bottom of the test tube. The test tube shall be surrounded with a water bath at a temperature of 60° F. The temperature of the bath shall be raised at a rate of 2° F. per minute to 100° F., then at a rate of 1° F. per minute until the first drop of petrolatum leaves the thermometer. The temperature at this instant shall be recorded.

Melting Point. 6. If the variation of three such determinations does not exceed 2° F., the average of these three determinations shall be reported as the melting point of the sample under test. If the variation of three determinations is greater than 2° F., two additional determinations shall be made and the average of five determinations reported as the melting point.

TENTATIVE DEFINITIONS OF TERMS RELATING TO PETROLEUM[1]

Serial Designation: D 288 – 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

Issued, 1928.

Crude Petroleum.—A naturally occurring mixture, consisting predominantly of hydrocarbons, and/or of sulfur, nitrogen and/or oxygen derivatives of hydrocarbons, which is removed from the earth in liquid state or is capable of being so removed.

Note.—Crude petroleum is commonly accompanied by varying quantities of extraneous substances such as water, inorganic matter and gas. The removal of such extraneous substances alone does not change the status of the mixture as crude petroleum. If such removal appreciably affects the composition of the oil mixture, then the resulting product is no longer crude petroleum.

Topped Crude Petroleum.—A residual product remaining after the removal, by distillation, or other artificial means, of an appreciable quantity of the more volatile components of crude petroleum.

Weathered Crude Petroleum.—The product resulting from crude petroleum through loss, due to natural causes, during storage and handling, of an appreciable quantity of the more volatile components.

Benzine.—This term is archaic and misleading and should not be used.

Petroleum Naphtha.—A generic term applied to refined, partly refined or unrefined petroleum products and liquid products of natural gas, not less than 10 per cent of which distills below 347° F. (175° C.) and not less than 95 per cent of which distills below 464° F. (240° C.), when subjected to distillation in accordance with the Standard Method of Test for Distillation of Gasoline, Naphtha, Kerosine, and Similar Petroleum Products (Serial Designation: D 86) of the American Society for Testing Materials.

Note.—The "naphthas" used for specific purposes such as cleaning, manufacture of rubber, manufacture of paints and varnishes, etc., are made to conform to specifications which may require products of considerably greater volatility than that set by the limits of this generic definition.

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[1] Criticisms of these Tentative Definitions are solicited and should be directed to Mr. R. P. Anderson, Secretary of Committee D-2 on Petroleum Products and Lubricants, 250 Park Ave., New York City.

Gasoline.—A refined petroleum naphtha which by its composition is suitable for use as a carburant in internal combustion engines.

Petroleum Spirits (White Spirits).—A refined petroleum distillate with a minimum flash point of 70° F. (21° C.) determined by the Tag Closed Tester in accordance with the Standard Method of Test for Flash Point of Volatile Flammable Liquids (Serial Designation: D 56) of the American Society for Testing Materials or by the Abel Tester, with volatility and other properties making it suitable as a thinner and solvent in paints, varnishes and similar products.

NOTE.—The term "turpentine substitute" as applied to petroleum spirits is to be condemned as false and misleading. The term "mineral spirits" which is frequently used in the paint and varnish industry is a misnomer as it includes within its scope not only petroleum products, but other hydrocarbon mixtures, such as coal-tar distillates. In Great Britain the term "petroleum spirits" is applied to a very light hydrocarbon mixture having a flash point below 32° F. (0° C.).

Kerosine.—A refined petroleum distillate having a flash point not below 73° F. (23° C.), as determined by the Abel Tester (which is approximately equivalent to 73° F. (23° C.) as determined by the Tag Closed Tester, A.S.T.M. Standard Method D 56) and suitable for use as an illuminant when burned in a wick lamp.

NOTE.—In the United States of America local ordinances or insurance regulations require flash points higher than 73° F. (23° C.), Tag Closed Tester.

Gas Oil.—A liquid petroleum distillate having a viscosity intermediate between that of kerosine and lubricating oil.

NOTE.—It should be understood that oils, other than gas oil as defined above, may be and are used in the manufacture of gas.

Fuel Oil.—Any liquid or liquefiable petroleum product used for the generation of heat in a furnace or firebox, the controlling factors being cost and adaptability. Fuel oils in common use fall into one of four classes: (*a*) Residual fuel oils, which are topped crude petroleums or viscous residuums obtained in refinery operations; (*b*) Distillate fuel oils, which are distillates derived directly or indirectly from crude petroleum; (*c*) Crude petroleums and weathered crude petroleums of relatively low commercial value; (*d*) Blended fuels, which are mixtures of two or more of the three classes.

Tar, Pitch.—These terms shall not be applied to petroleum products.

Petroleum Lubricating Grease.—A combination of a petroleum product and a soap or a mixture of soaps, suitable for certain types of lubrication.

Oil-Shale.—A compact rock of sedimentary origin, with an ash content of more than 33 per cent and containing organic matter that yields oil when destructively distilled but not appreciably when extracted with the ordinary solvents for petroleum.

Crude Shale Oil.—The oil obtained as a distillate by the destructive distillation of oil-shale.

End Point.—The highest temperature reading observed on the distillation thermometer during the distillation procedure conducted in accordance with the Standard Method of Test for Distillation of Gasoline, Naphtha, Kerosine and Similar Petroleum Products (Serial Designation: D 86) of the American Society for Testing Materials.

Engine Distillate.—A refined or unrefined petroleum distillate similar to naphtha, but often of higher distillation range.

Tops.—The unrefined distillate obtained in topping a crude petroleum.

TENTATIVE SPECIFICATIONS

FOR

HIGH-CARBON TAR CEMENT FOR USE COLD IN REPAIR WORK (CUT-BACK PRODUCT)[1]

Serial Designation: D 106 – 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1921; REVISED, 1923, 1925, 1927, 1928.

Properties. 1. The tar cement shall conform to the following requirements:

(*a*) Water.........................not more than 2.00 per cent

(*b*) Specific viscosity, Engler,[2] 50 cc. at 40° C. (104° F.)..35 to 80

(*c*) Distillation test on water-free material:

Total Distillate, by weight, 0 to 170° C. (32 to 338° F.)..................	1.00 to 8.00 per cent
Total Distillate, by weight, 0 to 235° C. (32 to 455° F.)..................	8.00 to 20.00 "
Total Distillate, by weight, 0 to 270° C. (32 to 518° F.)..................	16.00 to 28.00 "
Total Distillate, by weight, 0 to 300° C. (32 to 572° F.)..................	not more than 36.00 "
Residue, by weight..................	not less than 64.00 "

(*d*) Softening point (Ring-and-Ball Method) of residue from distillation test.......................not more than 65° C. (149° F.)

(*e*) Total Bitumen (Soluble in Carbon Disulfide)[3]..78 to 95 per cent

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 441 Lexington Ave., New York City.

[2] It is recommended that materials be called for under the following range and headings: Light 35 to 60, Heavy 60 to 80. The heavy material may require heating before use and care should be taken to avoid foaming on account of the possible water content.

[3] The specification range for total bitumen covers a wide variety of materials. If products from vertical retort or low-carbon coke-oven tars are desired, a range of 88 to 95 per cent should be specified. If high-carbon coke-oven or mixtures of coke-oven and gas-house tars are desired, a range of 78 to 88 per cent should be specified.

Methods of Testing.

2. The properties enumerated in these specifications shall be determined in accordance with the following methods of test of the American Society for Testing Materials, except as specified in Paragraph (*b*):

(*a*) *Percentage of Water:* Standard Method of Test for Water in Petroleum Products and Other Bituminous Materials (Serial Designation: D 95);[1]

(*b*) *Specific Viscosity:*[2] Method contained in *Bulletin No. 691*, U. S. Department of Agriculture, the instrument being standardized by the Bureau of Standards. The results shall be reported as specific viscosity compared with water at 25° C. (77° F.).

(*c*) *Distillation:* Tentative Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment (Serial Designation: D 20 - 28 T);[3]

(*d*) *Softening Point:* Standard Method of Test for Softening Point of Bituminous Materials (Ring-and-Ball Method) (Serial Designation: D 36);[4]

(*e*) *Total Bitumen:* Standard Method of Test for the Determination of Bitumen (Serial Designation: D 4).[5]

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[1] 1928 Supplement to Book of A.S.T.M. Standards, p. 148.

[2] The Engler test has not been standardized by the American Society for Testing Materials. Committees of the Society have under consideration the Saybolt Furol apparatus, which may be adopted later.

[3] See p. 943.

[4] 1927 Book of A.S.T.M. Standards, Part II, p. 496.

[5] *Ibid.*, p. 484.

TENTATIVE SPECIFICATIONS
FOR
LOW-CARBON TAR CEMENT FOR USE COLD IN REPAIR WORK (CUT-BACK PRODUCT)[1]

Serial Designation: D 107 - 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1921; REVISED, 1923, 1927, 1928.

Properties.

1. The tar cement shall conform to the following requirements:

(*a*) Water.......................not more than 2.00 per cent

(*b*) Specific viscosity, Engler,[2] 50 cc. at 40° C. (104° F.)..35 to 80

(*c*) Distillation test on water-free material:

Total Distillate, by weight, 0 to 170° C. (32 to 338° F.)	1.00 to 8.00	per cent
Total Distillate, by weight, 0 to 235° C. (32 to 455° F.)	8.00 to 20.00	"
Total Distillate, by weight, 0 to 270° C. (32 to 518° F.)	16.00 to 28.00	"
Total Distillate, by weight, 0 to 300° C. (32 to 572° F.)	not more than 36.00	"
Residue, by weight	not less than 64.00	"

(*d*) Softening point (Ring-and-Ball Method) of residue from distillation test.......................not more than 65° C. (149° F.)

(*e*) Total Bitumen (Soluble in Carbon Disulfide)..not less than 95 per cent

Methods of Testing.

2. The properties enumerated in these specifications shall be determined in accordance with the following methods of test of the American Society for Testing Materials, except as specified in Paragraph (*b*):

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 441 Lexington Ave., New York City.

[2] It is recommended that materials be called for under the following range and headings: Light 35 to 60, Heavy 60 to 80. The heavy material may require heating before use and care should be taken to avoid foaming on account of the possible water content.

(*a*) *Percentage of Water:* Standard Method of Test for Water in Petroleum Products and Other Bituminous Materials (Serial Designation: D 95);[1]

(*b*) *Specific Viscosity:*[2] Method contained in *Bulletin No. 691*, U. S. Department of Agriculture, the instrument being standardized by the Bureau of Standards. The results shall be reported as specific viscosity compared with water at 25° C. (77° F.).

(*c*) *Distillation:* Tentative Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment (Serial Designation: D 20 – 28 T);[3]

(*d*) *Softening Point:* Standard Method of Test for Softening Point of Bituminous Materials (Ring-and-Ball Method) (Serial Designation: D 36);[4]

(*e*) *Total Bitumen:* Standard Method of Test for the Determination of Bitumen (Serial Designation: D 4).[5]

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[1] 1928 Supplement to Book of A.S.T.M. Standards, p. 148.

[2] The Engler test has not been standardized by the American Society for Testing Materials. Committees of the Society have under consideration the Saybolt Furol apparatus, which may be adopted later

[3] See p. 943.

[4] 1927 Book of A.S.T.M. Standards, Part II, p. 496.

[5] *Ibid.*, p. 484.

TENTATIVE METHOD OF TEST FOR ABRASION OF GRAVEL[1]

Serial Designation: D 289 - 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1928.

Scope. 1. This method is intended to cover the abrasion of uncrushed and crushed gravel. Uncrushed gravel consists entirely of uncrushed fragments and, for the purpose of this test, a gravel containing more than 10 per cent by weight of crushed fragments shall be considered as crushed gravel.

APPARATUS

Deval Machine. 2. The standard Deval abrasion testing machine[2] shall be used for the test. The machine shall consist of one or more hollow cast-iron cylinders; closed at one end and furnished with a tightly-fitting iron cover at the other. The inside dimensions of the cylinders shall be 20 cm. in diameter and 34 cm. in depth. These cylinders shall be mounted on a shaft at an angle of 30 deg. with the axis of rotation of the shaft.

Abrasive Charge. 3. Six cast-iron spheres[3] 1.875 in. in diameter and weighing approximately 0.95 lb. (0.45 kg.) each, shall be used in the cylinder as an abrasive charge.

PREPARATION OF SAMPLE

Grading. 4. The gravel shall be separated by screening into the various sizes required for grading the test sample according to one of the gradings specified in Section 5. The material of these sizes shall be washed and dried.

Test Sample. 5. (*a*) The test sample shall consist of 5000 g. of dry gravel made up of percentages of the various sizes conforming to one of the following gradings. The grading selected for the test sample shall be that most nearly representing the gravel furnished for the work.

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[1] Criticisms of this Tentative Method are solicited and should be directed to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 441 Lexington Ave., New York City.

[2] This machine is the same as specified in the Standard Method of Test for Abrasion of Rock (Serial Designation: D 2), see the 1927 Book of A.S.T.M. Standards, Part II, p. 463.

[3] These spheres are the same as those used in the Rattler Test described in Sections 16 to 29 of the Tentative Specifications for Paving Brick (Serial Designation: C 7 - 28 T), see pp. 846 to 853.

Grading *A*	Passing a ¾-in. screen,[1] retained on a ½-in. screen	25 per cent
	" " 1-in. " " " " ¾-in. "	25 " "
	" " 1½-in. " " " " 1-in. "	25 " "
	" " 2-in. " " " " 1½-in. "	25 " "
Grading *B*	Passing a ¾-in. screen,[1] retained on a ½-in. screen	25 per cent
	" " 1-in. " " " " ¾-in. "	25 " "
	" " 1½-in. " " " " 1-in. "	50 " "
Grading *C*	Passing a ¾-in. screen,[1] retained on a ½-in. screen	50 per cent
	" " 1-in. " " " " ¾-in. "	50 " "
Grading *D*	Passing a ½-in. screen,[1] retained on a ¼-in. screen	50 per cent
	" " ¾-in. " " " " ½-in. "	50 " "

(*b*) When the gravel has a specific gravity below 2.20, a sample of 4000 g. instead of 5000 g. shall be used for the test.

(*c*) When the gravel furnished for the work contains as much as 25 per cent of material finer than ½ in. but is of such size that either Grading *A*, *B*, or *C* would be used for the abrasion test, a second abrasion test shall be made using Grading *D*, if, in the opinion of the engineer, the particles less than ½ in. in size are not at least equal in hardness to those particles ½ in. or over in size.

Crushed Gravel.

6. Gravel containing more than about 10 per cent by weight of crushed fragments (Note) shall, for the purpose of this test, be considered as crushed gravel. In such cases, the test sample shall contain crushed fragments so as to be representative of the gravel furnished for the work and shall be prepared in accordance with Sections 4 and 5.

NOTE.—For the purpose of this test, a crushed gravel fragment may be considered as a fragment of gravel having at least one fractured face.

PROCEDURE

Procedure.

7. The test sample and the abrasive charge shall be placed in the Deval machine and the cylinders shall be rotated at from 30 to 33 r.p.m. for 10,000 revolutions.[2] At the completion of the test, the material shall be removed from the machine and sieved on a No. 12 sieve conforming to the requirements of the Standard Specifications for Sieves for Testing Purposes (Serial Designation: E 11) of the American Society for Testing Materials.[3] The material retained

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[1] The question whether screens having round or square openings shall be used for testing is now being studied by the Section on Coarse Screens of the Technical Committee on Size and Shape of Committee E-1 on Methods of Testing.

[2] These requirements are the same as those specified in the Standard Method of Test for Abrasion of Rock (Serial Designation: D 2); see 1927 Book of A.S.T.M. Standards, Part II, p. 463.

[3] 1927 Book of A.S.T.M. Standards, Part II, p. 917.

upon the sieve shall be washed and dried and the weight accurately determined.

CALCULATION

Uncrushed Gravel. 8. In the case of uncrushed gravel, the loss by abrasion shall be considered as the difference between the original weight of the test sample and the weight of the material retained on the No. 12 sieve, expressed as a percentage of the original weight of the test sample.

Crushed Gravel. 9. In the case of crushed gravel, the percentage by weight of crushed fragments shall be determined and the permissible percentage of wear which shall govern shall be calculated from the following formula:

$$W = \frac{A\,L + (100 - A)\,L'}{100}$$

where

W = the permissible percentage of wear;
A = the percentage of uncrushed fragments;
$100 - A$ = the percentage of crushed fragments;
L = the maximum percentage of wear permitted by the specifications for gravel consisting entirely of uncrushed fragments;
L' = the maximum percentage of wear permitted by the specifications for gravel consisting entirely of crushed fragments.

TENTATIVE METHOD OF TEST
FOR
DISTILLATION OF BITUMINOUS MATERIALS SUITABLE FOR ROAD TREATMENT[1]

Serial Designation: D 20 - 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1926; REVISED, 1927, 1928.

This method is presented without any definition of its scope and accuracy since it is believed that it will become applicable to a wider range of materials than indicated by the title. So far the committee has determined its accuracy on one class of materials and further work will be done.

APPARATUS

Apparatus.

1. The apparatus consists of a flask, condenser tube, shield, receivers and thermometers as specified in Sections 2 to 6.

Flask.

2. *Flask.*—The distillation flask, Fig. 1, shall be a side neck distilling flask, having the following dimensions:

Diameter of bulb, outside	86	mm. ± 1.5 mm.
Diameter of neck, inside	22	mm. ± 1.0 mm.
Diameter of tubulature, inside	10.0	mm. ± 0.5 mm.
Length of neck	43	mm. ± 1.0 mm.
Distance, top of neck to tubulature	25	mm. ± 1.0 mm.
Length of tubulature	220	mm. ± 5.0 mm.
Angle of tubulature	73	deg. ± 1. deg.

Condenser Tube.

3. *Condenser Tube.*—The condenser tube shall be a suitable form of tapered glass tubing of the following dimensions:

Outside diameter of small end	12.5 mm.	permissible variation ± 1.5 mm.
Outside diameter of large end	28.5 mm.	permissible variation ± 3.0 mm.
Length	360.0 mm.	permissible variation ± 4.0 mm.
Length of tapered part	100.0 mm.	permissible variation ± 5.0 mm.

Shield.

4. *Shield.*—A galvanized iron shield, lined with $\frac{1}{8}$-in. asbestos, of the form and dimensions shown in Fig. 2 shall be used to protect the flask from air currents and to prevent radiation. The cover (top) may be of transit board made in two parts, or it may be of galvanized iron lined with $\frac{1}{8}$-in. asbestos.

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[1] Criticisms of this Tentative Method are solicited, and should be directed to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 441 Lexington Ave., New York City.

This tentative method is in effect a revision of the former Standard Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment (Serial Designation: D 20 - 18) which was accordingly discontinued in 1927.

Receiver. 5. *Receiver.*—The distillates will be collected in tared Erlenmeyer flasks having a capacity of 50 to 100 ml.

Thermometer. 6. *Thermometer.*—The thermometer shall conform to the following requirements. These specifications cover a total-immersion thermometer graduated in either Centigrade or Fahrenheit degrees as specified, the range being from 0 to 400° C. or 30 to 760° F., respectively.

TYPE: Etched stem, glass.

LIQUID: Mercury.

RANGE AND SUBDIVISION: 0 to 400° C. in 1° C. or 30 to 760° F. in 2° F.

TOTAL LENGTH: 378 to 384 mm. (14.88 to 15.12 in.).

STEM: Plain front, enamel back, suitable thermometer tubing. Diameter, 6.0 to 7.0 mm. (0.24 to 0.28 in.).

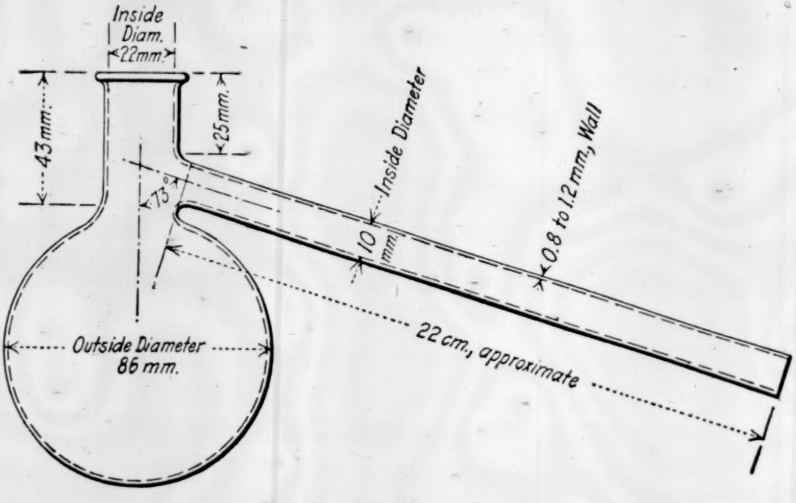

FIG. 1.—Distillation Flask.

BULB: Corning normal or equally suitable thermometric glass.
Length, 10 to 15 mm. (0.39 to 0.59 in.).
Diameter, 5.0 to 6.0 mm. (0.20 to 0.24 in.).

DISTANCE TO 0° C. OR 32° F. LINE FROM BOTTOM OF BULB: 25 to 35 mm. (0.98 to 1.38 in.).

DISTANCE TO 400° C. OR 752° F. LINE FROM TOP OF THERMOMETER: 30 to 45 mm. (1.18 to 1.77 in.).

FILLING ABOVE MERCURY: Nitrogen gas.

TOP FINISH: Glass ring.

GRADUATION: All lines, figures, and letters clear cut and distinct. The first and each succeeding 5° C. or 10° F. line to be longer than the remaining lines. Graduations to be numbered at each multiple of 10° C. or 20° F.

IMMERSION. Total.

SPECIAL MARKING: "A.S.T.M. High Distillation," a serial number and the manufacturer's name or trade mark shall be etched on the stem.

SCALE ERROR: The error at any point of the scale up to 370° C. or 700° F. when the thermometer is standardized as provided below shall not exceed 1° C. or 2° F.

STANDARDIZATION: The thermometer shall be standardized immersed in the testing bath to the top of the mercury column, at the ice point and at temperature intervals of approximately 50° C. or 100° F. up to 370° C. or 700 °F.

TEST FOR PERMANENCY OF RANGE: After being subjected to a temperature between 360 and 370° C. or 680 and 700° F. for 24 hours, the accuracy shall be within the limit specified.

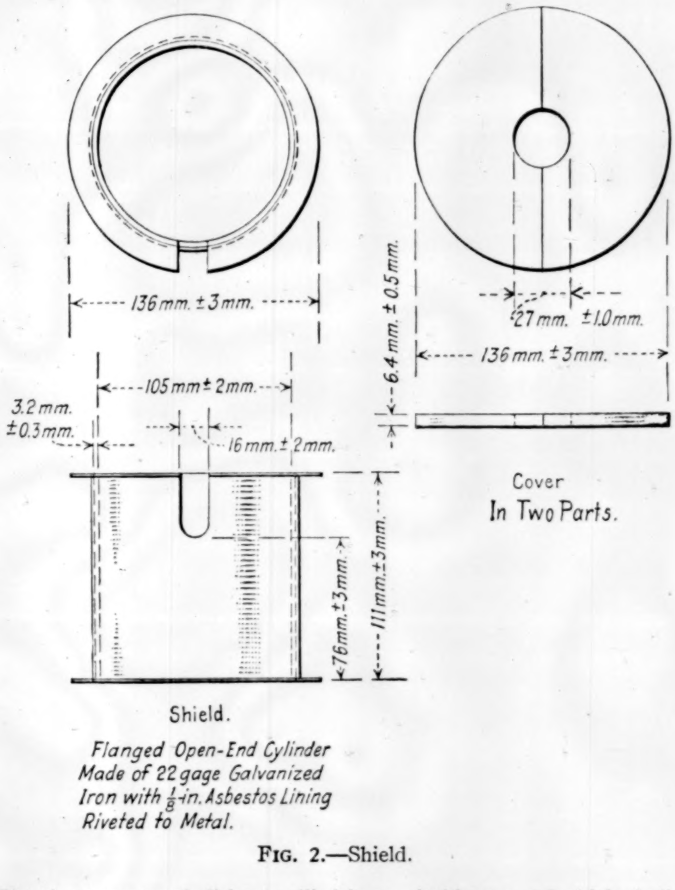
136 mm. ± 3 mm.
6.4 mm. ± 0.5 mm.
27 mm. ± 1.0 mm.
136 mm. ± 3 mm.
105 mm ± 2 mm.
3.2 mm. ±0.3 mm.
16 mm. ± 2 mm.
76 mm. ± 3 mm.
111 mm. ± 3 mm.
Cover
In Two Parts.
Shield.
Flanged Open-End Cylinder Made of 22 gage Galvanized Iron with ⅛-in. Asbestos Lining Riveted to Metal.

FIG. 2.—Shield.

CASE: The thermometer shall be supplied in a suitable case on which shall appear the marking: "A.S.T.M. High Distillation, 0 to 400° C." or "A.S.T.M. High Distillation, 30 to 760° F." according to the type of thermometer.

NOTE.—For the purpose of interpreting these specifications the following definitions apply:

The total length is the over-all length of the finished instrument.

The diameter is that measured with a ring gage.

The length of the bulb is the distance from the bottom of the bulb to the beginning of the enamel backing.

The top of the thermometer is the top of the finished instrument.

PREPARATION OF SAMPLE

Sampling. 7. The sample, as received, shall be thoroughly stirred and agitated, warming, if necessary, to insure a complete mixture before the portion for analysis is removed.

Dehydration. 8. The material may be tested for distillation without dehydration, if water is present not to exceed 2.0 per cent. If water is present in excess of 2.0 per cent, the bituminous material shall be dehydrated before distillation in accordance with the method for dehydration as given in Sections 2 to 4 of the Standard Methods of Sampling and Analysis of Creosote Oil (Serial Designation: D 38) of the American Society for Testing Materials.[1]

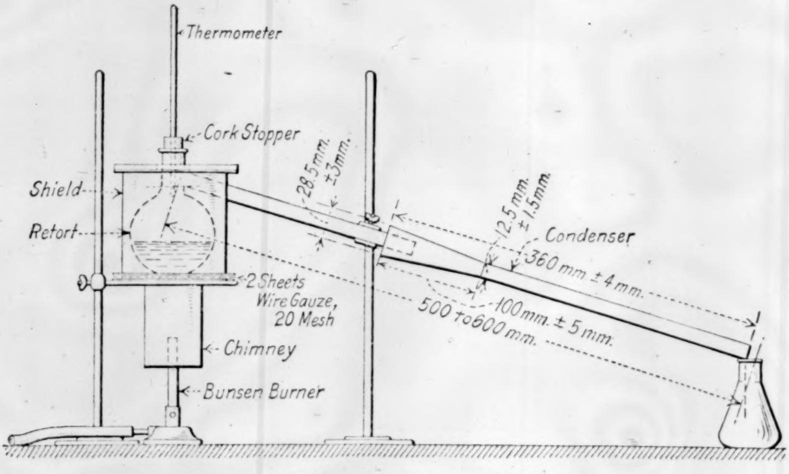

FIG. 3.—Distillation Apparatus Assembly.

PROCEDURE

Assembling Apparatus for Distillation Test. 9. (*a*) The flask shall be supported on a tripod or rings over two sheets of 20-mesh gauze, 150 mm. square, as shown in Fig. 3. It shall be connected to the condenser tube by a tight cork joint. The thermometer shall be inserted through a cork in the neck with the top of the bulb level with the lowest point of juncture of the tubulature and neck of the flask.

(*b*) The axis of the flask through the neck shall be vertical.

(*c*) The distance from the bulb of the thermometer to the outlet end of the condenser tube shall be not more than 600 nor less than 500 mm. The burner should be protected from draughts by a suitable shield or chimney (see Fig. 3).

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 683.

Distillation Test.

10. (*a*) One hundred grams (100 g. ± 0.1 g.) of the sample shall be weighed into the flask, the apparatus assembled and heat applied so that the first drop comes over in from 5 to 15 minutes. The distillation shall be conducted at the rate of between 50 and 70 drops per minute and the distillate collected in weighed receivers. The condenser tube shall be warmed whenever necessary to prevent accumulation of solid distillates. The fraction shall be collected at the points designated by the specifications. The receivers shall be changed when the thermometer indicates the maximum temperature for each fraction. When the maximum specified temperature of the test is indicated by the thermometer, the flame shall be removed and any oil which has condensed in the condenser tube shall be drained into the last fraction.

(*b*) The residue shall remain in the flask with the cork and thermometer in position until no vapors are visible and it shall then be weighed. If tests of the residue are required, the flask shall then be inclined so that the residue will flow around the sides, thus collecting any condensed vapors that may be on the sides of the flask, after which the residue shall be poured into a suitable receptacle and covered. If the residue becomes so cool that it cannot be poured readily from the flask, it shall be reheated to a temperature not exceeding 125° C. by holding the bulb of the flask in a suitable bath and not by the application of flame.

For weighing the receivers and fractions, a balance accurate to at least 0.05 g. shall be used.

(*c*) During the progress of the distillation the thermometer shall remain in its original position. No correction shall be made for the emergent stem of the thermometer.

(*d*) The results of the distillation test shall be reported in percentages by weight of water-free material. The following fractions are usually reported:

Up to 170° C.
170 to 235° C.
235 to 270° C.
270 to 300° C.
Residue.

TENTATIVE METHOD OF TEST
FOR
RESIDUE OF SPECIFIED PENETRATION[1]

Serial Designation: D 243 - 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1926; REVISED, 1928.

Scope. 1. This method of test covers the determination of percentage of residue having a specified penetration at 100 g., 5 seconds, 25° C. (77° F.), obtained by heating a road oil or a semi-solid asphalt having a penetration of more than 100, at a temperature of 249 to 260° C. (480 to 500° F.). When the penetration of the residue is not otherwise stated it shall be understood to be 100. The residue obtained is available for tests as desired.

APPARATUS

Apparatus. 2. The apparatus shall consist of an iron dish, flask heater, thermometer, Bunsen burner, tripod and stand with a thermometer clamp. The dish, flask heater and thermometer shall be as specified in Sections 3, 4 and 5.

Container. 3. The container for holding the sample to be tested shall be a hemispherical iron dish having the following dimensions:

Diameter at the top, outside	12.7 cm. ±0.3 cm.
Depth, inside	5.7 cm. ±0.2 cm.
Radius of curvature, inside	6.0 cm. ±0.1 cm.

NOTE.—A hemispherical iron sand bath, deep form of 5 in. in diameter, should meet these requirements.

Heater. 4. The flask heater shall be in the form of a truncated cone, with a diameter at the top of approximately 18.0 cm., a diameter at the bottom of approximately 5.2 cm., and a height of approximately 7.0 cm. It shall be made of sheet iron of about No. 22 gage with asbestos strips riveted to the sides, and with a sheet iron shield at the bottom.

Thermometer. 5. The thermometer shall conform to the following requirements.[2] These specifications cover a special thermometer graduated to either Centigrade or Fahrenheit degrees as specified, the ranges being −6 to +400° C., or +20 to +760° F., respectively.

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[1] Criticisms of this Tentative Method are solicited, and should be directed to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 441 Lexington Ave., New York City.

[2] These specifications are the same as for the open cup flash point thermometer specified in the Standard Method of Test for Flash and Fire Points by Means of Open Cup (Serial Designation: D 92), 1927 Book of A.S.T.M. Standards, Part II, p. 404.

TYPE: Etched stem, glass.

LIQUID: Mercury.

RANGE AND SUBDIVISION: -6 to +400° C. in 2° C. or +20 to +760° F. in 5° F.

TOTAL LENGTH: 303 to 307 mm. (11.92 to 12.08 in.).

STEM: Plain front, enamel back, suitable thermometer tubing.
Diameter, 6.0 to 7.0 mm. (0.24 to 0.28 in.).

BULB: Corning normal or equally suitable thermometric glass.
Length, not over 13 mm. (0.51 in.).
Diameter, not greater than stem.

DISTANCE TO -6° C. OR 20° F. LINE FROM BOTTOM OF BULB: 40 to 50 mm. (1.57 to 1.97 in.)

DISTANCE TO 400° C. OR 760° F. LINE FROM TOP OF THERMOMETER: 30 to 45 mm. (1.18 to 1.77 in.).

FILLING ABOVE MERCURY: Nitrogen gas.

TOP FINISH: Red glass ring.

GRADUATION: All lines, figures, and letters clear cut and distinct. The first and each succeeding 10° F. line to be longer than the intermediate lines. Graduations to be numbered at each multiple of 20°.

IMMERSION: 25 mm. or one inch. The words "1-in. immersion" on Fahrenheit thermometers or "25-mm. immersion" on Centigrade thermometers and a line around the stem 25.4 mm. or 1.00 in. above the bottom of the bulb shall be etched on the thermometer.

SPECIAL MARKING: "A.S.T.M. Open Flash" a serial number and the manufacturer's name or trade mark shall be etched on the stem.

SCALE ERROR: The error at any point of the scale when the thermometer is standardized as provided below shall not exceed 1° C. up to 372° C. or 2.5° F. up to 700° F.

STANDARDIZATION: The thermometer shall be standardized at the ice point and at intervals of approximately 100° F. for 25-mm. or 1-in. immersion and for the following temperatures of the emergent mercury column:

THERMOMETER READING		AVERAGE TEMPERATURE OF EMERGENT MERCURY COLUMN	
100° C.	200° F.	44° C.	110° F.
150° C.	300° F.	54° C.	129° F.
200° C.	400° F.	64° C.	150° F.
250° C.	500° F.	77° C.	175° F.
300° C.	600° F.	91° C.	205° F.
350° C.	700° F.	108° C.	240° F.

TEST FOR PERMANENCY OF RANGE: After being subjected to a temperature between 360 to 370° C. or 680 to 700° F. for 24 hours, the accuracy shall be within the limit specified.

CASE: The thermometer shall be supplied in a suitable case on which shall appear the marking: "A.S.T.M. Open Flash, -6 to +400° C." or "A.S.T.M. Open Flash, +20 to +760° F.," according to the type of thermometer.

NOTE.—For the purpose of interpreting these specifications the following definitions apply:

The total length is the over-all length of the finished instrument.

The diameter is that measured with a ring gage.

The length of the bulb is the distance from the bottom of the bulb to the beginning of the enamel backing.

The top of the thermometer is the top of the finished instrument.

PREPARATION OF SAMPLE

Preparation of Sample.

6. The sample as received shall be thoroughly stirred and agitated, to insure a complete mixture before the portion for testing is removed.

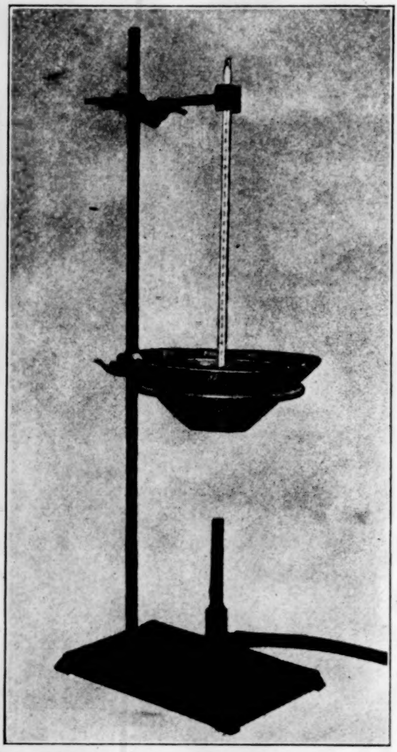

FIG. 1.—Assembly of Apparatus.

PROCEDURE

Procedure.

7. One hundred grams (100.00 ± 0.10 g.) of the material to be tested shall be weighed into a tared container, which shall then be placed in the flask heater in position to be heated. The thermometer shall be supported in the sample equi-distant from the sides of the container and with the bottom of the bulb neither more than $\frac{1}{4}$ in. above nor touching the bottom of the container. The bulb shall be completely immersed in the sample throughout the heating. An assembly of the apparatus is shown in Fig. 1.

8. The sample should be heated as rapidly as possible, to prevent foaming, to a temperature of 249° C. (480° F.) and during the evaporation, the temperature shall be maintained between 249° C. (480° F.) and 260° C. (500° F.). The sample shall be stirred with the thermometer from time to time to prevent local overheating and, to maintain a homogeneous sample, all cakes of hardened bitumen which form at the sides of the container shall be fluxed in the sample.

An experienced operator can judge approximately what percentage of residue he should obtain to secure the desired penetration. When it is supposed that the residue will show the required penetration, the bitumen on the thermometer which may be readily scraped off shall be returned to the container, which then shall be removed from the flask heater, cooled and weighed. The penetration of the residue shall then be determined in accordance with the Standard Method of Test for Penetration of Bituminous Materials (Serial Designation: D 5) of the American Society for Testing Materials.[1]

9. It frequently is necessary to make several trials before a residue of the required penetration is obtained. If it is determined to be greater than that required, all water shall be removed from the container and the surface of the sample, and the heating and determination of penetration may be repeated as before. Ordinarily a residue shall be considered as satisfactorily obtained when its penetration is within 15 of that desired, and its percentage by weight of the original sample shall be calculated. When it is necessary to determine more precisely the percentage of residue having the specified penetration, such a percentage shall be computed by interpolation between percentages of two residues, one having a penetration greater and one having a penetration lower than that specified. The percentage shall be reported as:

Percentage of residue of .... penetration (determined ....) stating, first, the specified penetration, and second, the penetration actually determined for the sample tested or calculated by interpolation.

PRECAUTIONS

10. Certain types of road oil will readily form rings of hard asphalt at the side of the container. Great care should be taken that this material be completely fluxed in the sample before the penetration of the residue is determined. **Precautions.**

ACCURACY

11. Duplicate determinations should not differ by more than 1.0 per cent with the same operator nor more than 2.5 per cent between different laboratories. **Accuracy.**

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[1] 1927 Book of A.S.T.M. Standards, Part II, p .493.

TENTATIVE METHODS OF TESTING BITUMINOUS EMULSIONS[1]

Serial Designation: D 244 - 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

Issued, 1926; Revised, 1928.

1. For testing purposes, emulsions shall be classified as follows:

I. Emulsified light oils or liquid petroleum products intended for dust laying purposes.

II. Emulsified asphaltic materials, the asphalt content of which is of a consistency suitable for construction or repair.

- (*a*) Containing little or no mineral matter.
- (*b*) Containing appreciable quantities of mineral matter.

METHOD FOR DETERMINING MISCIBILITY OF BITUMINOUS EMULSIONS WITH WATER

(Applicable to Both Classes I and II)

2. To about 50 cc. of the emulsion shall be gradually added about 150 cc. of distilled water, stirring the mixture while adding the water. The temperature is not important but should be between 21 and 25° C. (70 and 79° F.). The mixture shall be allowed to stand for 2 hours and then examined for any appreciable separation.

STONE COATING TEST

(Applicable Only to Emulsions of Class II (*a*))

3. Four hundred and sixty-five grams of clean stone ($\frac{1}{4}$ to $\frac{3}{4}$ in. in size, not more than 5 per cent passing a $\frac{1}{4}$-in. screen and 100 per cent passing a $\frac{3}{4}$-in. screen), see Tentative Specifications for Commercial Sizes of Broken Stone and Broken Slag for Highway Construction (Serial Designation: D 63 - 23 T) of the American Society for Testing Materials,[2] of either trap or hard limestone shall be placed

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[1] Criticisms of these Tentative Methods are solicited, and should be directed to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 441 Lexington Ave., New York City.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part I, p. 709 (1923); also 1928 Book of A.S.T.M. Tentative Standards, p. 450.

in a No. 10 sieve, drenched and washed with distilled water, allowed to drain for 3 minutes and transferred to a suitable pan in which the mixture is to be made. (A 6-in. hemispherical iron dish has been found suitable and satisfactory for this purpose.) Thirty-five grams of the emulsion shall then be added to and mixed vigorously with the stone for 3 minutes. (A steel spatula is satisfactory for mixing.) There shall be no signs of appreciable separation of the asphalt contained in the emulsion during the 3-minute mixing period.

METHOD FOR DETERMINATION OF WATER, OIL DISTILLED WITH WATER AND PREPARATION OF ASPHALTIC BASE FOR FURTHER TESTS

(A) Method Applicable to Emulsions of Class II (a) Only

4. The apparatus shall consist of an iron still, 6 in. by $3\frac{1}{2}$ in. in inside diameter with an air adjustable ring burner to fit the still. The still shall be provided with a connecting tube of approximately 12-mm. diameter glass tubing, a tin shield, a condenser trough, a condenser tube, and a suitable graduated cylinder. A thermometer 0 to 400° C. shall be provided conforming to the requirements for the thermometer specified in Section 6 of the Tentative Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment (Serial Designation: D 20 - 28 T) of the American Society for Testing Materials.[1] The apparatus shall be set up as shown in Fig. 1. The still shall be charged with 200 g. of the well-mixed sample. An oiled paper gasket shall be applied to the flange at the top of the still and the cover clamped on securely. The thermometer shall be placed in position so that the tip of the bulb is $\frac{1}{2}$ in. from the inside bottom of the still. A gentle heat shall be applied to the top of the still by the ring burner. Just sufficient heat shall be applied to the connecting tube to prevent condensation of water therein.

The heat shall be applied to the extreme upper part of the still, until practically all of the water has distilled over, or until a temperature of 121° C. (250° F.) has been reached. The ring burner shall then be lowered very gradually to a position midway between the top and bottom of the still and held there until the temperature is about 176° C. (349° F.). The ring burner shall then be lowered more rapidly to within $\frac{1}{4}$ in. of the bottom of the still and the temperature then raised to 260° C. (500° F.) and maintained for 15 minutes. This period of heating is important to insure a smooth homogeneous residue in the still.

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[1] See p. 943.

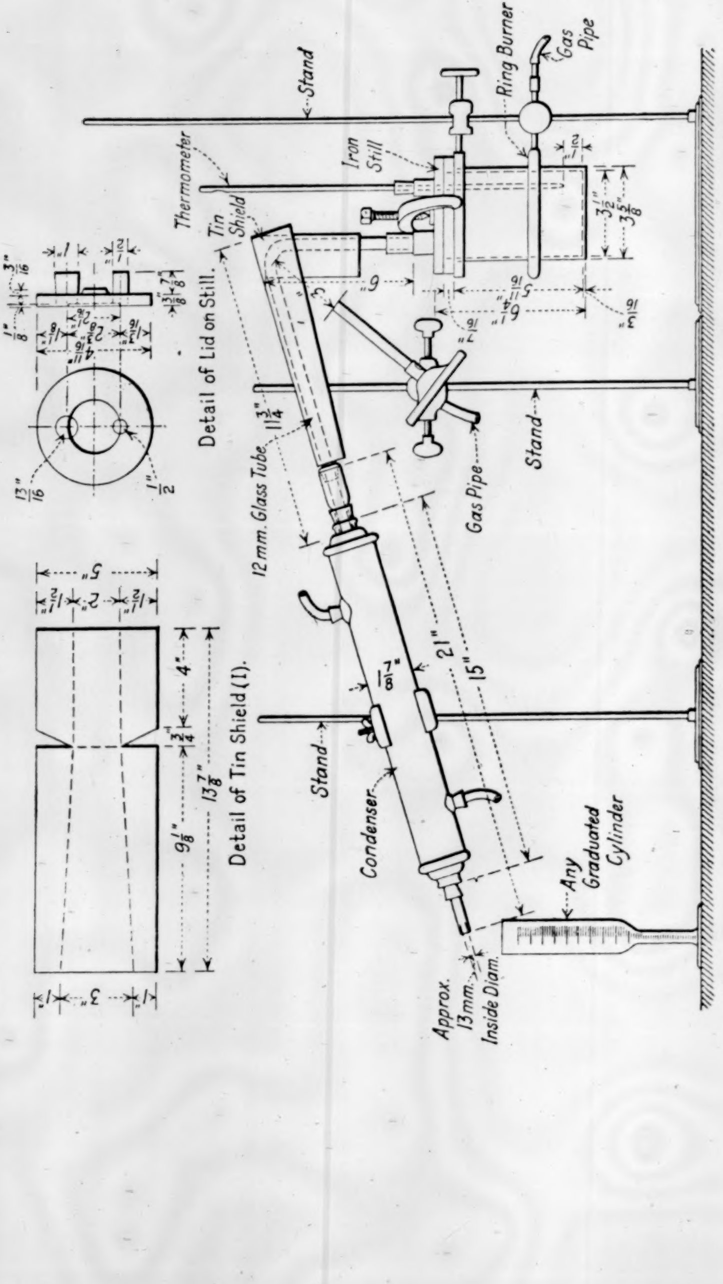
Detail of Tin Shield (I).
Detail of Lid on Still.
Stand
Thermometer
Tin Shield
Iron Still
Ring Burner
Gas Pipe
12 mm. Glass Tube
Gas Pipe
Stand
Condenser
Any Graduated Cylinder
Approx. 13 mm. Inside Diam.
5"
2"
4"
3/4"
9 1/8"
13 7/8"
3"
11 3/4"
1 7/8"
21"
15"
3 1/2"
3 5/8"
13/16"
1/2"

FIG. 1.—Assembly for Distillation Test for Bituminous Emulsions.

The cover shall then be removed from the still and the hot residue poured into a ductility mold and into a standard 3-oz. tin box for the penetration test, the receptacles being left uncovered. While cooling, any excess shall be poured into suitable containers for any additional tests desired.

Any water or oil remaining in the condenser tube shall be forced out carefully into the graduated cylinder, by means of a rubber stopper fixed on the end of a long rod.

The distillation should be completed in not less than 1 hour and in not more than 1¼ hours.

If the residue is not homogeneous and appears granular, it shall be rejected and the distillation repeated upon a fresh sample, maintaining the temperature at 260° C. (500° F.) for slightly more than 15 minutes.

The number of cubic centimeters of water divided by 2 is the per cent by weight of water.

The weight of residue remaining in the still divided by 2 is the percentage of non-volatile matter under the conditions of this test.

The sum of the percentage of water and non-volatile matter deducted from 100 represents distilled oils.

(*B*) *Method Applicable to Emulsions of Class II* (*b*)

Water.—The water shall be determined by the distillation method above described.

Oils.—Two 50-g. samples of well-mixed emulsion shall be placed in a standard 3-oz. tin box, in an oven at 163° C. (325° F.) for 5 hours, and the loss determined. If the loss is greater than the percentage of water (see preceding paragraph) it would indicate the presence of volatile oils and the difference in the two determinations would closely approximate the percentage of volatile oil.

The residue of the 50-g. sample shall be dissolved in benzol, filtered, and the filtrate evaporated on a water bath until practically all the benzol is evaporated, then placed in an oven at 105° C. (221° F.) for 30 minutes and finally heated on a hot plate to 121° C. (250° F.) with constant stirring. The consistency, ductility or other tests desired are made upon this residue.

Mineral Matter.—The mineral matter on the filter paper from the extraction shall be dried and weighed or a separate determination on a smaller sample of the original emulsion may be made.

TENTATIVE RECOMMENDED PRACTICE
FOR
BITUMINOUS PAVING PLANT INSPECTION[1]

Serial Designation: D 290 – 28 T

This is a **Tentative Standard**, published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

Issued, 1928.

Scope. 1. This recommended practice defines the authority and duties of the inspector at a bituminous paving plant.

Definitions

Definitions. 2. (*a*) *Engineer.*—Throughout this recommended practice the term engineer shall be construed to mean the engineer in responsible charge of the work or his duly recognized or authorized laboratory; or in the absence of an engineer the purchaser or his duly authorized laboratory.

(*b*) *Contractor.*—The term contractor shall be construed to mean the party to the contract who has agreed to supply materials and perform work in accordance with the specifications, or his duly authorized representative at the plant.

(*c*) *Laboratory.*—The term laboratory shall be construed to mean any supervising laboratory duly authorized by the engineer to direct and advise the inspector in the discharge of his duties.

(*d*) *Plant Laboratory.*—The term plant laboratory shall be construed to mean the laboratory operated by or under the direction of the plant inspector at the plant.

RESPONSIBILITIES AND GENERAL DUTIES OF INSPECTOR

Authority. 3. The inspector shall be provided with written authority from the engineer to enable him to insist on the fulfillment of specifications covering materials, plant procedure and products; and the rejection of such materials, procedure and products failing to comply with the specifications. The inspector shall have available a copy of the specifications applying to the particular project and shall be furnished immediately in writing with copies of all modifications, amendments and instructions affecting the product of the plant. The inspector shall recognize the right of the contractor to use such apparatus, methods, and personnel as he deems proper, providing it is within the specifications. Any appeal on the part of the contractor from rejections shall be made in writing to the engineer, with a copy to the inspector, unless otherwise provided in the contract.

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[1] Criticisms of this Recommended Practice are solicited and should be directed to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 441 Lexington Ave., New York City.

Cooperation.

4. It shall be the duty of the plant inspector to cooperate in every reasonable way with the contractor so as to assist in obtaining economical and efficient plant operation; and with the pavement inspector in all plant matters relating to the economical production of a satisfactory material conforming to the specifications.

Duties.

5. In addition to the responsibilities specified in Sections 3 and 4, the duties of the plant inspector shall be:

(*a*) To ascertain that the plant is equipped and operated at all times in conformity with the specifications, see Section 6.

(*b*) To collect and submit to the laboratory or to test, as directed, samples of materials to be used at the plant, see Sections 7 to 13, inclusive, and Table I.

(*c*) To control the proportions and temperatures of mixtures and of materials within such limits as are assigned to him, and to insure that the products of the plant are otherwise in accordance with the specifications, see Sections 14 to 18.

(*d*) To conduct required plant-laboratory tests of materials, see Sections 19 to 24.

(*e*) To record the output of the plant, and, as required, the delivery and consumption of materials at the plant, see Section 25.

(*f*) To fulfill other assigned duties, see Section 26.

(*g*) To submit daily reports, see Sections 27 and 28.

PLANT EQUIPMENT AND OPERATION

Plant Equipment and Operation.

6. The inspector shall ascertain as early as possible that the plant is equipped in accordance with specifications and capable of producing a mixture conforming to the requirements of the specifications. He shall also determine if the liners, gate and blades of the mixer are in satisfactory condition for efficient mixing. He must make all necessary determinations of the accuracy of scales, using standard weights, and of the volume of various containers if used in the proportioning of mixtures. During the operation of the plant he shall check at frequent intervals the accuracy of various scales used in determining the weight of each material. He shall examine screens used in separating heated aggregates for bin storage to see that

the screen openings are of the proper size, and that the various screen sections are properly placed over the bins.

SAMPLING

Sampling. 7. As far as possible in advance, and preferably at least three to five days before beginning work on each contract, samples of each material to be used in the mixtures shall be collected by the inspector and submitted to the laboratory or tested by him as directed as shown in Table I. Should the sources of supply of any material received change from that represented by the inspector's first sample, new samples shall be submitted by the inspector.

Marking. 8. Beginning at the start of operations on a given contract, the inspector shall assign class designations to each class of material being sampled, and each sample selected shall be numbered serially in that class, continuing numerically until the completion of the work. Care shall be taken that the series of numbers is not broken or numbers duplicated. All samples sent to the laboratory shall be marked in such a manner as to insure complete identification. Letters and numbers may be scratched or punched clearly on tin cans, and marked with ink or paint on other sample containers or on sections of pavement.

Asphalt Cement. 9. (*a*) Daily control samples of asphalt cement and mixtures shall be selected and, at the end of the day's work, forwarded to the laboratory in a manner to arrive at the laboratory in the shortest possible time.

(*b*) Daily samples of asphalt cement which the inspector has tested for penetration shall be forwarded to the laboratory.

Crude Asphalt, Refined Asphalt and Flux. 10. When forwarding samples of crude asphalt, refined asphalt and flux to the laboratory, in the inspection covering the manufacture of asphalt blocks, information shall also be furnished relative to the proportions by weight being used so that proper combination can be made for analysis and check determinations.

Sheet Asphalt Surface Mixture. 11. Daily samples of sheet asphalt surface mixtures shall be obtained by the inspector for the laboratory. Each sample shall consist of small quantities from not less than ten, and preferably more, separate batches. The portions selected shall be molded into a container provided for that purpose. Care shall be taken in selecting and after collection of these samples to prevent contamination by dust or other foreign material. It is desirable to scrape away the top material in a batch before sampling to prevent any contamination.

Bituminous Concrete. 12. (*a*) *Control Samples.*—Daily samples of bituminous concrete mixtures shall be taken by the inspector, using either method (*1*)

TABLE I.—INDEX OF SAMPLING BITUMINOUS PAVING MATERIALS.

Material		Method	Quantity	When Collected	By Whom Tested
Asphalt Sand		Standard Methods of Sampling Stone, Slag, Gravel, Sand and Stone Block for Use as Highway Materials, Including Some Material Survey Methods (Serial Designation: D 75) of the American Society for Testing Materials.[1]	5 lb.	Each car or boat and truck deliveries by special instructions from preliminary or first shipments from given source or when source or supply changes or if change occurs in materials received.	Laboratory.
				Daily from subsequent shipments, and sand in use from stock pile.	Plant Laboratory.
Screenings		Same as for asphalt sand.	5 lb.	Same as for asphalt sand.	Same as for asphalt sand.
Crushed Stone		Same as for asphalt sand.	15 to 20 lb.	Same as for asphalt sand.	Same as for asphalt sand.
Filler		Composite from eight to ten sacks, mixing and quartering.	5 lb.	Same as for asphalt sand.	Same as for asphalt sand.
Heated Aggregates		By use of shovel as aggregate flows from storage bin.	5 to 20 lb., depending whether coarse or fine aggregate.	At least daily.	Plant Laboratory.
Asphalt Cement	A	Standard Methods of Sampling Bituminous Materials (Serial Designation: D 140) of the American Society for Testing Materials.[2]	1 qt.	Each car or boat.	Laboratory.
	B	In metal container from valve over asphalt bucket on plant. Mixed and poured into 3-oz. can.	3 oz.	Daily.[3]	Plant Laboratory and Laboratory.
Crude Asphalt		Standard Methods of Sampling Bituminous Materials (Serial Designation: D 140) of the American Society for Testing Materials.[2]	1 qt.	Each car or boat.	Laboratory.
Refined Asphalt			1 qt.	Each car or boat.	Laboratory.
Flux			1 qt.	Each car or boat.	Laboratory.
Finished Mixtures	A. To determine average daily analysis of mixture.	Composite from number of batches.	4 oz., minimum, for sheet asphalt; 5 lb., minimum, for asphaltic concrete or binder.	Daily.	Laboratory.
	B. For determination of uniformity of individual or different batches.	From individual batches.	4 oz., minimum, for sheet asphalt; 5 lb., minimum, for asphaltic concrete or binder.	As directed.	Laboratory.
Asphalt Block		Select blocks representative of production.	2 blocks.	Daily.	Laboratory.

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 473.

[2] *Ibid.*, p. 515.

[3] When fluxing at paving plants, preliminary 3-oz. samples shall also be taken from each melting kettle, when ready and completely mixed. This is in addition to daily 3-oz. sample as provided above.

or (*2*) as given below. Care shall be taken to avoid segregation of either stone or bituminous mortar, and in selecting the portions of the sample care shall be taken to scrape away the top material in a load so as to avoid dust or any segregated unrepresentative mixture. Precautions shall also be taken to prevent contamination, by dust or other foreign material, of the sample after collection.

> (*1*) Take small portions from a number of batches and store them on a metal plate until near the end of the day. At the end of this time heat the entire mass, taking care not to apply too high a temperature, mix thoroughly, and select the sample in small portions from this mass.
>
> (*2*) Collect portions from one or more batches on a large shovel, thoroughly mix while still warm, and place a representative scoopful directly in a container. This operation shall be repeated as often as possible to represent a maximum number of batches.

(*b*) *Uniformity Samples.*—Samples shall be taken by the inspector as directed to show the uniformity of the mixture by either selecting three separate portions from separate distinct spots in the batch, or by selecting a representative sample from different individual batches throughout a day's run. The samples collected shall be placed in separate containers and each container shall be properly identified and distinctly marked uniformity sample, furnishing also the temperature and length of time the batch was mixed.

Rejected Materials.

13. Samples of all materials rejected by the inspector shall be forwarded to the laboratory.

PREPARATION OF MIXTURES

Proportioning Materials.

14. Within the limits of the specifications, the inspector shall receive instructions from the engineer in regard to the desired proportion of each ingredient that enters into a mixture and the range of proportions within which he should work. It is advisable whenever possible to have entire loads of the mixture weighed, as a further check on the weight or volumetric proportioning being used in the plant.

Volumetric Proportioning.

15. (*a*) *Dry Aggregates.*—When dry, heated sand or stone are measured by volume, their weights per cubic foot hot shall be determined in order to compute the proportions. The weight per cubic foot of the filler shall also be determined at the approximate temperature of use for calculating the correct amount to be added.

(*b*) *Wet Aggregates.*—When wet sand, stone, or screenings are being measured by volume, the moisture content of each shall be determined by drying a representative sample and calculating the percentage of moisture. Deductions for moisture shall be made from the weights of each material forming the total batch in calculating the required amount of asphalt cement. The percentage of moisture in aggregates shall always be entered on the daily report. The determination shall be made frequently on sand and fine screenings. Loss of fine mineral matter through heating shall be compensated for by the use of additional filler in proportioning.

Proportioning by Weight.

16. (*a*) Asphalt cement shall always be measured by weight. The actual percentage of bitumen in the asphalt cement should be ascertained from the laboratory in order to determine the proportion of asphalt cement to be used in the mixture.

(*b*) The inspector should note whether the scales on the mixing platform are being handled carefully, taking care that the aggregate hoppers and asphalt bucket swings freely during the weighing and that the beam is brought to a floating position. He should note whether the asphalt bucket is drained completely for each batch, and check the tare weight of the empty asphalt bucket at frequent intervals so as to compensate for the amount of asphalt clinging to the bucket after each pouring. Particular attention shall be paid to this point in cool weather and at times when there has been a long interval between loads.

Combining Aggregates.

17. (*a*) The inspector shall give particular attention to the combination of aggregates before they enter the drier, and especially to the combination of fine aggregates. Where the proportions of the final mixture are dependent upon the supply of aggregates to a belt conveyor or elevator, he shall see that the supply of each aggregate to the conveyor is continuous and uniform. When two or more kinds of aggregate are combined on the ground and measured in such containers as wheelbarrows, which must be of equal volumes, the containers shall be struck off to a level surface, irregular heaping shall not be permitted.

(*b*) The inspector shall make certain that the man at the mixer allows mineral aggregates to become thoroughly mixed before the addition of asphalt cement, and that the time of mixing is sufficient to prepare a uniform mixture.

Temperature of Materials.

18. The inspector shall take the temperature of all ingredients of the mixture, especially mineral aggregates, and of the mixtures, as frequently as possible. He should assist plant employees in every way in keeping temperatures uniform by notifying the plant foreman

of any marked changes that he may observe. Should the aggregates be of improper temperature, mixing operations shall be discontinued until aggregates of the proper temperature are obtained.

The desired temperatures at the plant will depend upon the kind of mixture being prepared, the type of asphalt being used, weather conditions, and the length of haul. The inspector should receive instructions as to the temperature range desired for each contract.

PLANT TESTING OF MATERIALS

Sand.

19. *Sand.*—The sands shall be tested daily in accordance with the Standard Method of Mechanical Analysis of Sand or Other Fine Highway Material, Except Fine Aggregates Used in Cement Concrete (Serial Designation: D 7) of the American Society for Testing Materials.[1] When two or more grades of sand are being received for use in combination, separate mechanical analysis shall be made on shipments of each variety and the resultant combination calculated and shown on the daily report. The proportions in which sands are combined shall also be shown on the report.

Filler.

20. *Filler.*—A sample of the filler shall be thoroughly dried, 50 g. accurately weighed, and the amount passing the No. 200 sieve shall be determined in accordance with Sections 29 to 32, inclusive, of the Standard Specifications and Tests for Portland Cement (Serial Designation: C 9) of the American Society for Testing Materials.[2] If any appreciable amount of filler is retained on the No. 200 sieve, the mechanical analysis of the coarser material shall be obtained in the same manner as in testing sand, see Section 22.

Screenings.

21. *Screenings.*—The mechanical analysis of screenings shall be determined on a dried sample of not less than 250 g., and if the screenings are very coarse or contain a considerable percentage of particles larger than ½ in. in diameter, an amount up to 500 g. may be used. The sample shall be sieved on a No. 10 sieve and the percentages retained on and passing this sieve shall be determined. If the amount passing the No. 10 sieve is much greater than 100 g. a portion of it, after thorough mixing, may be selected by quartering and the mechanical analysis made in accordance with the test used for sand, see Section 22. The percentages retained on each sieve shall be calculated on the basis of the original sample. The portion retained on the No. 10 sieve shall be sieved over various coarser sieves as may be required.

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 479.

[2] *Ibid.*, p. 23.

Stone.

22. *Stone.*—The crushed stone shall be examined for grading in accordance with the Standard Method of Mechanical Analysis of Broken Stone or Broken Slag, Except Aggregates Used in Cement Concrete (Serial Designation: D 18) of the American Society for Testing Materials.[1] When stone is being used from a large stock pile, frequent mechanical analyses shall be made as the work progresses.

Asphalt Cement.

23. (*a*) *Asphalt Cement.*—The inspector shall make daily penetration tests of each tank of asphalt cement used in the day's work. The sample shall be placed in 3-oz. tin boxes and the test made in accordance with the Standard Method of Test for Penetration of Bituminous Materials (Serial Designation: D 5) of the American Society for Testing Materials.[2] After the test, all water shall be drained from the samples and the boxes closed with tightly fitting lids for shipment to the laboratory.

(*b*) A working range of ten points penetration for the asphalt cement will usually be set by the specifications for each contract, and if results should show a deviation beyond this range a check determination shall be made. The inspector should be instructed as to what action he should take when the penetration of asphalt cement is not within the prescribed limits.

Heated Aggregates.

24. *Heated Aggregates from Bins.*—Samples of aggregates which have passed through the drying and heating process shall be taken and tested at least once each day, and more frequently if necessary, to determine the uniformity of bin materials. Samples may be secured by passing a shovel or pan quickly through the stream of hot material as it flows from the storage bin. All tests of these materials shall be recorded on the plant report. The results will show: (1) when blended materials are being used, whether mixing is being carried on satisfactorily; (2) whether separation of aggregates by sizes has been complete. If the dried sand is contaminated with stone, steps shall be taken to determine the cause and to make correction.

REPORT

Production of Plant.

25. The inspector shall record daily the time and hours of operation of the plant, the number of batches and number of loads of each type of mixture produced, and also the total amounts of each material used during the day and on hand at the end of the day. At times, the inspector may be required to record the locations at which mixtures were laid on the road.

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 481.

[2] *Ibid.*, p. 493.

Miscellaneous Data. 26. When obtainable, the inspector may be required to report cost data, including the hours of work for each classification of labor, trucks, superintendents, etc., and the rates of compensation.

Daily Reports. 27. At the close of each working day, whether the plant is in operation or not, the inspector shall forward to the engineer and laboratory a consecutively numbered daily report, using a form which gives all the required information. All data pertinent to the work not covered by the form should be given on the reverse side of the report sheet, and communications of exceptional importance only should be sent separately from the report. When work is suspended for several days, the inspector may not be required to submit reports daily, but the last report should state why and for what periods work has been discontinued. The inspector shall retain copies of these reports and communications and, in addition, keep a daily record of all matters pertaining to his work, particularly as to his action in acceptance or rejection of materials with reasons therefor, instructions or suggestions to the contractor, and receipt of instructions from the engineer or laboratory.

Report Form. 28. A standard form of report is not practicable for all conditions and types of pavement, but the report form appended hereto is a typical form showing the kind of information which should be included; additional data may be called for as required.

ASPHALT PLANT REPORT

STATE OR COUNTY	CITY, TWP. OR BORO.
STREET, ROUTE, APPL.	SEC. NO. OR BLOCK

Date..................19........Weather..........................Temp. A. M..............P. M..............F. A. P. No..............Eng. Dist...............
Type of Const..Type of Plant..Location of Plant..
Contractor...Amount of Contract.........................Sq. Yd
Binder or S. C. Sta.................................to Sta.......................................Lineal ft. S. C. or Binder...
W. S. or B. C. Sta...................................to Sta.......................................Lineal ft. W. S. or B. C...

COURSE	TEMPS.			NO. BATCHES	HR. IN OPERATION	SQ. YD. LAID
	MAX.	MIN.	AVE.			
Binder or S. C.						
W. S. or B. C.						

Binder or S. C., lb. per sq. yd.	
W. S. or B. C., lb. per sq. yd.	
Total, lb. per sq. yd.	
No. of sq. yd. laid to date, Completed Pav't	
No. of sq. yd. laid today, Completed Pav't	
No. of sq. yd. laid, total, Completed Pav't	

PLANT LABOR	NO.	HOURS	TOTAL HOURS
Foremen			
Engineers			
Skilled Labor			
Unskilled Labor			
Trucks			
Total Hours			

MATERIALS	KIND OR BRAND	TONS ON HAND	TONS USED
Refined Asphalt			
Flux			
Asphaltic Cement			
Filler (Dust)			
Portland Cement			
Sand			
Gravel			
Crushed Stone			
Screenings			
Coal			
Coke			
Fuel Oil (gal.)			
Lub. Oil (gal.)			

	SAMPLED FROM	SAND				STONE				SCREENINGS		PENETRATIONS		SAMPLES TO LABORATORY	
												NO.	TEST		
PER CENT PASSING	No. 200													W. S.	
	No. 80													B. C.	
	No. 40													S. C.	
	No. 10													A. C.	
	¼ in.													R. A.	
	½ in.														
	¾ in.													Filler	
	1 in.													Sand	
	1¼ in.													Screenings	
	Ret. on 1¼ in.													Stone	
	Total														

TEMPERATURES					TANK NO. 1 A. C.	TANK NO. 2 A. C.
Max.						
Min.						
Ave.						

BATCH WEIGHTS AND PERCENTAGE OF MIXTURES

MATERIAL	BINDER (LB.)	PER CENT	W. S. (LB.)	PER CENT	B. C. (LB.)	PER CENT	S. C. (LB.)	PER CENT	
A. C.									
Filler (Dust)									
Sand									
Screenings									
Stone									
Total									

Time arrived..
Beginning of operation ....
Time taken for lunch...
Time departed ....

Record of Official Inspections...
Calculations..................Notes to Lab....................Remarks..................
Shown on reverse side (check items to which reference is made).

....Inspector.

NOTE:
A. C. = Asphalt Cement.
B. C. = Bituminous Concrete.
R. A. = Refined Asphalt.
S. C. = Seal Coat.
W. S. = Wearing Surface.

TENTATIVE METHOD OF TEST
FOR
CUBIC FOOT WEIGHT OF CRUSHED BITUMINOUS COAL[1]

Serial Designation: D 291 - 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1928.

APPARATUS

Cubic Foot Weight Box.

1. A box 12 by 12 by 12 in. in inside dimensions shall be used. A box made of $\frac{1}{8}$-in. sheet steel welded together and provided with handles, makes a very suitable cubic foot box and would weigh approximately 35 lb.

SAMPLING

Gross Sample.

2. For collecting gross samples of crushed bituminous coal, the procedure described in Sections 1 to 4, inclusive, and the directions preceding Section 1 of the Standard Method of Sampling Coal (Serial Designation: D 21) of the American Society for Testing Materials[2] shall apply. During the period of collecting the gross sample, the increments of the sample shall be stored in a waterproof container with a tightly fitting cover in order to prevent the loss of moisture.

Laboratory Sample.

3. The gross sample of coal shall, as quickly as possible to avoid loss of moisture, be thoroughly mixed and reduced by quartering, without crushing, to a laboratory sample of approximately 60 lb. in accordance with Sections 6 and 7 of the Standard Method D 21. The cubic foot weight should be determined immediately. If the determination of the cubic foot weight is not to be made immediately, the 60-lb. laboratory sample should be kept in a waterproof container with a tightly fitting cover until the time for making the determination.

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[1] Criticisms of this Tentative Method are solicited and should be directed to Mr. W. A. Selvig, Secretary of Committee D-5 on Coal and Coke, U. S. Bureau of Mines, 4800 Forbes St., Pittsburgh, Pa.

[2] 1927 Book of A.S.T.M. Standards, Part II, p. 530.

PROCEDURE

Procedure.

4. The cubic foot weight box shall be placed on a suitable platform scale, weighed empty and then filled with crushed bituminous coal from the laboratory sample while the box is on the scale in order to avoid handling the heavy box of coal. The box shall be filled by means of a scoop or small shovel by allowing the coal to slide off the scoop or shovel from a height of 2 in. above the top of the box until the coal overflows on all sides of the box. Precaution should be taken that none of the coal is dropped into the box so as to cause packing and that the cubic foot box is not shaken or tapped during filling. The excess coal shall be struck off by means of a straight edge without shaking or tapping the box. The box filled with coal shall then be weighed. The difference between the two weights to the nearest 0.1 lb. shall be reported as the weight of one cubic foot of the crushed bituminous coal.

NOTE.—Aside from the character of the coal itself, moisture content and size of the coal are the two main factors which affect the cubic foot weight. A moisture determination and a sieve analysis of the coal should be reported along with the cubic foot weight for proper interpretation of the cubic foot weight.

For directions for making the moisture determination see the Standard Method of Laboratory Sampling and Analysis of Coal and Coke (Serial Designation: D 271) of the American Society for Testing Materials.[1]

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 535.

TENTATIVE METHOD OF TEST FOR CUBIC FOOT WEIGHT OF COKE[1]

Serial Designation: D 292 - 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1928.

APPARATUS

Cubic Foot Weight Box. 1. A box 24 by 24 by 24 in. in inside dimensions shall be used. In order to keep the weight of the empty box as light as possible, the box may be made of wood but it must be rigid. Two strips of wood may be fastened to the sides of the box to form "sedan-chair" handles for convenience in handling.

NOTE.—For determining the cubic foot weight of coke smaller than 1 in. in size, a cubic foot weight box measuring 12 by 12 by 12 in. in inside dimensions may be used.

SAMPLING

Gross Sample. 2. For collecting samples of coke, the procedure described in Sections 1 to 4, inclusive, and the directions preceding Section 1 of the Standard Method of Sampling Coal (Serial Designation: D 21) of the American Society for Testing Materials[2] shall apply in general. The weight of the sample selected for the determination of the cubic foot weight depends upon the size and character of the coke and shall conform to the following:

For run-of-oven coke and coke 1 in. and larger in size.	not less than 300 lb.
For coke smaller than 1 in. in size..................	not less than 50 lb.

It is extremely difficult to obtain truly representative samples of coke having a range of sizes. When the coke is on a belt conveyor the sample shall be selected by stopping the belt at regular intervals and selecting increments in sections about 3 ft. in length and the entire width of the belt or when the coke is going over a pulley or coming down a chute the sample shall be selected by inserting a container or scoop into the stream of coke at regular intervals so as to take increments of the full width and thickness. The increments shall be regularly and systematically collected, so that the entire quantity of coke sampled will be represented proportionately in the sample, and with such frequency that a sample of the required amount shall be collected. It is not feasible to collect representative samples of coke from loaded cars or bins for cubic foot weight determinations. Samples of coke in cars or bins should be taken as the cars or bins are being filled or emptied.

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[1] Criticisms of this Tentative Method are solicited and should be directed to Mr. W. A. Selvig, Secretary of Committee D-5 on Coal and Coke, U. S. Bureau of Mines, 4800 Forbes St., Pittsburgh, Pa.

[2] 1927 Book of A.S.T.M. Standards, Part II, p. 530.

PROCEDURE

Procedure.

3. The cubic foot weight box shall be placed on a suitable platform scale, weighed empty and then filled with coke from the sample while the box is on the scale in order to avoid handling the heavy box of coke. The box shall be filled by means of a shovel or other suitable container by allowing the coke to slide out of the shovel or container from a height of 2 in. above the top of the box, with no attempt to spread or arrange the coke. Because of the physical character of coke, it is not practical to strike off the excess coke by means of a straight edge, so it is necessary to do this largely by eye, with the assistance of a straight edge to check observations. The box shall not be shaken, tapped or dropped during filling or leveling off. The box filled with coke shall then be weighed. The difference between the two weights divided by the number of cubic feet in the box will give the weight per cubic foot of coke.

NOTE.—For proper interpretation of the cubic foot weight of coke, a moisture determination and a sieve analysis of the coke should be reported along with the cubic foot weight. For directions for making these determinations see the following methods of the American Society for Testing Materials:

In the case of a moisture determination, the Standard Methods of Laboratory Sampling and Analysis of Coal and Coke (Serial Designation: D 271);[1]

In the case of a sieve analysis, the Tentative Method of Test for Sieve Analysis of Coke (Serial Designation: D 293 - 28 T).[2]

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 535.

[2] See p. 970.

TENTATIVE METHOD OF TEST
FOR
SIEVE ANALYSIS OF COKE[1]

Serial Designation: D 293 – 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1928.

APPARATUS

Sieves. 1. The following square-mesh sieves, so selected that the actual openings between the wires of the succeeding sizes of sieves shall have a constant ratio of 1.414 (the square root of 2), in so far as this sieve scale has become established by use, shall be used: 0.131, 0.185, 0.263, 0.371, 0.525, 0.742, 1.050, 1.5, 2.0, 3.0 and 4.0 in. In accordance with the Standard Specifications for Sieves for Testing Purposes (Serial Designation: E 11) of the American Society for Testing Materials[2] a tolerance of ±3 per cent on average openings and of 10 per cent in maximum openings are permissible. For sizes of coke smaller than 2 in., sieves of double-crimped wire with circular frames about 18 in. in diameter are satisfactory. For coke 2 in. and larger in size, it is more convenient to use sieves square or rectangular in shape of heavy, double-crimped wire having an area of 6 to 9 sq. ft. These larger sieves may be mounted in a rack so as to slide like a drawer with a pan at the bottom.

SAMPLING

Sample. 2. For collecting samples of coke, the procedure described in Sections 1 to 4, inclusive, and the directions preceding Section 1 of the Standard Method of Sampling Coal (Serial Designation: D 21) of the American Society for Testing Materials[3] shall apply in general. The weight of the sample selected for the sieve-analysis determination depends upon the size and character of the coke and shall conform to the following:

For run-of-oven coke and coke 1 in. and larger in size containing breeze	not less than 500 lb.
For coke 1 in. and larger in size, free from breeze	not less than 200 lb.
For coke smaller than 1 in. in size	not less than 50 lb.

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[1] Criticisms of this Tentative Method are solicited and should be directed to Mr. W. A. Selvig, Secretary of Committee D-5 on Coal and Coke, U. S. Bureau of Mines, 4800 Forbes St., Pittsburgh, Pa.

[2] 1927 Book of A.S.T.M. Standards, Part II, p. 917.

[3] *Ibid.*, p. 530.

It is extremely difficult to obtain truly representative samples of coke having a range of sizes. When the coke is on a belt conveyor the sample shall be selected by stopping the belt at regular intervals and selecting increments in sections about 3 ft. in length and the entire width of the belt, or when the coke is going over a pulley or coming down a chute the sample shall be selected by inserting a container or scoop into the stream of coke at regular intervals so as to take increments of the full width and thickness. The increments shall be regularly and systematically collected, so that the entire quantity of coke sampled will be represented proportionately in the sample, and with such frequency that a sample of the required amount shall be collected. It is not feasible to collect representative samples of coke from loaded cars or bins for sieve analyses. Samples of coke in cars or bins should be taken as the cars or bins are being filled or emptied.

PROCEDURE

Procedure. 4. The sample shall be accurately weighed. Starting with the sieve having the largest opening, the sample of coke shall be sieved in such increments as will allow the pieces to be in direct contact with the meshes after the completion of the shaking of each increment. For coke 1 in. and larger in size the following square-mesh sieves are usually used: 4.0 in., 3.0 in., 2.0 in., 1.5 in., 1.050 in. and 0.525 in. For coke smaller than 1 in. in size the square-mesh sieves usually used are: 0.742 in., 0.525 in., 0.371 in., 0.263 in., 0.185 in. and 0.131 in. Each piece of coke retained on the 2-in. or larger sieve shall be up-ended on the sieve, that is, tested to see if it will in any position pass through the sieve. Coke pieces passing the 2-in. sieve shall be shaken rather vigorously on each succeeding sieve in order to up-end the pieces until practically no more coke will pass through the openings. The coke retained on each sieve and that which passes the smallest sieve used shall be weighed separately. In case the coke is wet, the coke shall be dried before making the sieve analysis. However, usually any error due to moisture content would be very small and may be neglected except in the case of coke smaller than 1 in. in size, in which case the coke shall be dried before making the sieve test.

Report. 5. The sieve analysis of the coke shall be reported in percentage to the nearest 0.1 per cent as follows:

	PER CENT
Retained on a 4.0-in. sieve	....
Passing a 4.0-in. sieve, retained on a 3.0-in. sieve	....
Passing a 3.0-in. sieve, retained on a 2.0-in. sieve	....
Passing a 2.0-in. sieve, retained on a 1.5-in. sieve	....
Passing a 1.5-in. sieve, retained on a 1.050-in. sieve	....
....	....
....	....
Passing a 0.185-in. sieve, retained on a 0.131-in. sieve	....
Passing a 0.131-in. sieve	....
Total	100.0

In case the sum of the percentages do not total 100.0, correction shall be made on the quantity passing through the smallest sieve so that the total will be 100.0. However, if the sum of the weights retained on each sieve and that which passes the smallest sieve shows a loss of over 0.5 per cent, the analysis shall be rejected and another test made.

In view of the difficulty of obtaining representative samples of coke with regard to the size of pieces, even when 500-lb. samples are used for the sieve analysis, it is desirable to take several samples for sieve tests and average the figures for the several samples.

TENTATIVE METHOD OF TUMBLER TEST
FOR
COKE[1]

Serial Designation: D 294 - 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1928.

APPARATUS

Tumbler Machine. 1. The tumbler machine shall consist of a circular steel drum 36 in. in inside diameter and 18 in. in inside length made of plate at least $\frac{1}{4}$ in. in thickness. Two equally-spaced 2 by 2 by $\frac{1}{4}$-in. angles shall be riveted longitudinally inside the drum. These angles shall be riveted to the shell so that the attached legs point away from the direction of rotation, thus giving a clear unobstructed shelf for lifting the coke. The drum shall be mounted on a horizontal shaft to provide for rotating the drum. An opening shall be provided, preferably in the shell, for introducing and removing the sample. During the test, the cover shall be rigidly fastened to the shell and shall be so constructed as to fit into the shell in order to have a smooth inner surface.

Sieves. 2. For sizing the sample for test, square-mesh sieves having 2-in. and 3-in. actual openings between the wires shall be used. For sieving the coke after the tumbler test, square-mesh sieves having 2-in., 1.5-in., 1.050-in., 0.525-in., and 0.263-in. actual openings between the wires shall be used. In accordance with the Standard Specifications for Sieves for Testing Purposes (Serial Designation: E 11) of the American Society for Testing Materials[2] a tolerance of ±3 per cent on average openings and of 10 per cent in maximum openings are permissible. Sieves of heavy double-crimped wire with circular frames about 24 in. in diameter are satisfactory.

SAMPLING

Collecting Sample. 3. The quantity of coke collected for sizing shall be sufficient to obtain approximately 25 lb. of coke which will pass a 3-in. and be retained on a 2-in. square-mesh sieve. This may best be accomplished by placing a container or scoop in the stream of coke and collecting small increments at regular intervals in order to obtain a representative sample of the entire quantity of coke under consideration.

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[1] Criticisms of this Tentative Method are solicited and should be directed to Mr. W. A. Selvig, Secretary of Committee D-5 on Coal and Coke, U. S. Bureau of Mines, 4800 Forbes St., Pittsburgh, Pa.

[2] 1927 Book of A.S.T.M. Standards, Part II, p. 917.

Sizing Sample. 4. The coke shall be sized by sieving on a 3-in. and a 2-in. square-mesh sieve, without crushing the larger pieces, in order to obtain a sample that will pass the 3-in. and be retained on the 2-in. sieve. In sizing the sample, each piece of coke shall be up-ended on the sieve, that is, tested to see if it will in any position pass the sieve. If a large proportion of the pieces are larger than 3 in., it will be necessary to break-out representative smaller pieces of the desired size. This shall be accomplished without shattering the coke pieces and may often be done with a heavy screw driver by prying apart at fracture cracks.

PROCEDURE

Procedure. 5. Approximately 22 lb. (10 kg.) of the coke sample which has been sized in accordance with Section 4, and previously dried at 104 to 200° C., shall be accurately weighed and placed in the drum of the tumbler machine. The cover shall be rigidly fastened and the drum rotated at 24 r.p.m. ± 1 r.p.m. for a total of 1400 revolutions. All of the coke shall then be removed from the drum and sieved, using the following square-mesh sieves: 2-in., 1.5-in., 1.050-in., 0.525-in., and 0.263-in. Each piece of coke retained on the 2-in. sieve shall be up-ended to determine whether in any position it passes the 2-in. sieve, while the coke passing the 2-in. sieve shall be shaken rather vigorously on each succeeding sieve in order to up-end the pieces until practically no more coke will pass through the openings. The coke retained on each sieve and that which passes through shall be weighed separately.

REPORT

Report. 6. The sieve analysis after the tumbler test shall be reported in cumulative percentages to the nearest 0.1 per cent, as follows:

	Per Cent, Cumulative	
Total retained on the 2-in. sieve	....	
Total retained on the 1.5-in. sieve	....	
Total retained on the 1.050-in. sieve	....	Stability Factor
Total retained on the 0.525-in. sieve	....	
Total retained on the 0.263-in. sieve		Hardness Factor

Names have been assigned to two values in the sieve test following the tumbler test. The percentage of coke retained on the 1.050-in. sieve has been designated the stability factor and the percentage retained on the 0.263-in. sieve as the hardness factor as indicated in the report of the sieve test in the above table.

TENTATIVE METHODS OF TESTING INSULATING VARNISHES[1]

Serial Designation: D 115 - 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1921; REVISED, 1922, 1923, 1924, 1925, 1926, 1928.

Scope. 1. These tests are intended for varnishes which are applied by brushing, dipping or spraying, and are primarily for the purpose of providing electrical insulation.

SPECIFIC GRAVITY

Specific Gravity. 2. The specific gravity shall be measured with a pycnometer, Westphal balance or with a hydrometer so graduated that the specific gravity can be determined to 0.001. The temperature of the varnish shall be not less than 18° C. (64.4° F.) nor more than 22° C. (71.6° F.) and corrected to 20° C. (68° F.) by applying a correction of 0.0007 per 1° C. (0.0004 per 1° F.).

VISCOSITY

Viscosity. 3. The viscosity shall be determined at 20° C. (68° F.) and the results shall be stated in terms of absolute viscosity — poise[2] or centipoise (centipoise = 0.01 poise).

NOTE 1.—When measurements are made by an indirect method, the instrument used must be standardized. Oils of standard viscosity for use in standardizing such instruments can be obtained from the U. S. Bureau of Standards.

NOTE 2.—A description of the MacMichael viscosimeter as remodeled and improved for varnish testing may be obtained from the secretary of Committee D-9 together with directions for its calibration in absolute units.

FLASH POINT

Procedure for Flash Point. 4. The flash point shall be determined in accordance with the Standard Method of Test for Flash Point of Volatile Flammable

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[1] Criticisms of these Tentative Methods are solicited and should be directed to Mr. T. S. Taylor, Secretary of Committee D-9 on Electrical Insulating Materials, Bakelite Corporation, 230 Grove St., Bloomfield, N. J.

[2] The absolute viscosity of a material or its viscosity in absolute units (c.g.s., poises) has been defined as the force in dynes required to move, at a velocity of 1 cm. per second, one surface having an area of 1 sq. cm. past another parallel like surface 1 cm. away, overcoming the resistance to shear of the material filling the space between.

Liquids (Serial Designation: D 56) of the American Society for Testing Materials.[1]

TIME OF DRYING

Test Specimen.

5. (*a*) Specimens for this test shall be pieces of thoroughly cleaned, smooth sheet copper or brass about 3 cm. (1.18 in.) wide and 20 cm. (7.88 in.) long and about 0.127 mm. (0.005 in.) thick.

(*b*) The specimen shall be dipped once in the varnish at a room temperature of approximately 20° C. (68° F.) and withdrawn slowly and uniformly (about 38 cm. (15 in.) per minute). The consistency of the varnish shall be first so adjusted by trial that, when dry as determined in accordance with Section 7, the thickness of the film of varnish on each side of the metal shall be between 0.022 mm. (0.0009 in.) and 0.026 mm. (0.001 in.). Care shall be taken before dipping the specimens that the varnish has stood in the dipping tank for a sufficient length of time to be free from air bubbles.

Procedure.

6. (*a*) Specimens of air-drying varnish shall be dried in dust-free air at a room temperature of approximately 20° C. (68° F.).

(*b*) In the case of baking varnishes, six specimens shall be dipped and allowed to drain at a room temperature of approximately 20° C. (68° F.) until the varnish is set as indicated when the impression left on the surface by pressing lightly thereon with a finger will not become obliterated by further flow of the material. They are then to be dried in dust-free air in an oven at 105 to 110° C. (221 to 230° F.). At the end of the first 30 minutes, and again at the end of each 10-minute period thereafter, one specimen shall be taken from the oven and examined. In the case of slow-drying varnishes, this 10-minute period may be lengthened at the discretion of the operator.

Time of Drying.

7. The varnish shall be considered dry when a specimen will not stick to itself when folded and pressed together between the thumb and finger at a temperature of approximately 20° C. (68° F.).

DIELECTRIC STRENGTH TEST[2]

Dielectric Strength Test Specimen.

8. (*a*) Specimens for the dielectric strength test shall be prepared by dipping pieces of kraft paper about 20 cm. (7.88 in.) square and about 0.076 mm. (0.003 in.) thick into the varnish which shall be at the consistency prescribed in Section 5 (*b*).

NOTE.—The paper used shall be that which is commercially known as No. 1 Sulfate Kraft. The surface of the paper shall be smooth, free from pimples or lumps and reasonably free from hairy fibers. The paper shall also be free from conducting particles, slime spots, creases, cuts, specks or other "paper defects."

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 300

[2] This test is relative only, but it gives more uniform results than those obtained with a copper base. See the Appendix for a procedure for determining the dielectric strength on a copper base.

(*b*) Each specimen shall be dipped twice, as specified in Section 5 (*b*), once in each direction, in order to give a more uniform thickness of coating. The specimen shall be dried after each dip in the same vertical position in which it was dipped.

(*c*) Specimens of air-drying varnish shall be dried in dust-free air after each dip at a room temperature of approximately 20° C. (68° F.) for a period 600 per cent longer than that determined in accordance with Section 7, provided such period does not exceed 24 hours.

(*d*) Specimens of baking varnish shall be drained and then baked in dust-free air after each dip for a period 300 per cent greater than that determined in accordance with Section 7 provided such period does not exceed 24 hours.

(*e*) The final thickness of the specimen shall be 0.152 mm. (0.006 in.) to within ± 15 per cent.

Procedure.

9. (*a*) The dielectric strength of the specimen shall be determined by applying alternating potential to two circular metal disks, 5.08 cm. (2.0 in.) in diameter and with edges rounded to a radius of 0.64 cm. (0.25 in.) which are placed in contact with the two sides of the specimen directly opposite each other and under a pressure of approximately 0.5 kg. (1.1 lb.). Starting at zero, the voltage shall be increased uniformly to breakdown at a rate of 0.5 kv. per second, except that if breakdown occurs at this rate in less than 40 seconds, the rate shall be decreased so that breakdown will occur in not less than 40 seconds. If the material fails at less than 5 kilovolts, the minimum time shall be reduced from 40 seconds to 20 seconds. Ten such punctures are to be made at various points selected at random on each specimen. In each test the thickness of the specimen is to be determined as close to the point of puncture as practicable.

NOTE.—When necessary, in order to get ten punctures, additional specimens should be tested.

(*b*) The frequency of the test potential shall be not greater than 100 cycles per second, and each part of the testing apparatus shall have a continuous rating of not less than 2 kva. (preferably larger). The wave form shall be a sine curve as defined, and the voltage shall be measured by methods approved by the American Institute of Electrical Engineers.[1]

(*c*) The voltage may be controlled by any approved method which does not distort the wave form beyond the limits prescribed above and which does not subdivide the voltage in steps greater than

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[1] Standards of the American Institute of Electrical Engineers.

500 volts. The apparatus shall comply with the Standards of the American Institute of Electrical Engineers.

Dielectric Strength.

10. The volts at puncture, the thickness of the specimen and the volts per mil of thickness shall be reported for each of the ten tests, together with the average, maximum and minimum volts per mil.

WATER ABSORPTION TEST

Procedure.

11. Specimens similar to those described in Section 8 shall be immersed in water at a room temperature of approximately 20° C. (68° F.) for a period of 24 hours. Upon removal from the water, the surface water shall be wiped off and dielectric strength tests made immediately as described in Section 9.

Dielectric Strength.

12. The volts at puncture, the thickness of the specimen and the volts per mil of thickness shall be reported for each of the ten tests, together with the average, maximum and minimum volts per mil.

HEAT ENDURANCE TEST

Test Specimens.

13. (*a*) For the heat endurance test, specimens shall be prepared by dipping pieces of thoroughly cleaned, smooth sheet copper or brass about 20 cm. (7.88 in.) square and about 0.127 mm. (0.005 in.) thick into the varnish which shall be at the consistency prescribed in Section 5 (*b*).

(*b*) The specimens shall be dipped twice as prescribed in Section 5 (*b*).

(*c*) After removing not less than 1.27 cm. (0.5 in.) from one edge of the specimens the number of strips required by Section 14 (*a*) shall be cut from the same edge each 1.9 cm. (0.75 in.) in width.

Procedure.

14. (*a*) After setting as shown by the test indicated in Section 6 (*b*), the strips referred to in Section 13 shall be placed in a uniformly heated oven in which the temperature is maintained at 100° C. (212° F.) within ± 5° C. (9° F.). A strip shall be removed at the end of 1, 2, 4, 8 and 24 hours respectively and every 24 hours thereafter. These, together with the initial strip, shall be tested as follows at a room temperature of approximately 20° C. (68° F.).

(*b*) Each strip shall be bent through 180 deg. over a rod 0.32 cm. ($\frac{1}{8}$ in.) in diameter. The number of hours of baking at which first cracking in the insulation occurs shall be noted and reported

ACID AND ALKALI PROOF TEST

Test Specimens.

15. The specimens to be used for the test for acid and alkali proofness shall be brass rods 1.5 cm. (0.59 in.) in diameter, 15 cm.

(5.90 in.) long and carefully rounded at one end to a radius of 0.75 cm. (0.295 in.). These specimens shall be dipped three times into the varnish, leaving exposed about 3 cm. (1.18 in.) of the rod at the end opposite the rounded end. Each coat shall be dried 25 per cent longer than the period determined in Section 7. Three specimens each shall be prepared for the acid and alkali solutions.

Procedure.

16. (*a*) The three specimens shall be suspended in the acid or alkali whose effect it is desired to determine to within 3 cm. (1.18 in.) of the end of the coated portion of the rod and suitable provision made for detecting the change in the electrical resistance between the rod and the solution.

NOTE.—A simple method is to connect a voltmeter between each rod in turn and one side of a 110 volt direct current circuit, the other side of the circuit being connected to the solution through any piece of suitable metal suspended in the solution. The resistance will be inversely proportional to the deflection of the voltmeter pointer, that is, the smaller the deflection, the greater the resistance. Failure of the material will, therefore, be indicated by a sudden increase in the deflection of the voltmeter pointer.

(*b*) It is recommended that these tests be made in 10-per-cent solutions as follows:

Sulfuric acid of sp. gr. 1.069 at 60° F. (15.5° C.) or nitric acid of sp. gr. 1.056 at 60° F. (15.5° C.) or hydrochloric acid of sp. gr 1.050 at 60° F. (15.5° C.) and sodium hydroxide of sp. gr. 1.115 at 60° F. (15.5° C.).

(*c*) The temperature of the solution shall be kept at approximately 20° C. (68° F.).

Acid and Alkali Proofness.

17. The resistance between each rod and the solution shall be measured once per day and the number of days elapsing before breakdown occurs shall be taken as the "proofness" of the varnish.

OIL PROOF TEST

Oil Test Specimen.

18. (*a*) To test for the effect of oil, the specimens shall be prepared as prescribed in Section 13 (*a*).

(*b*) The specimens shall be dipped and dried as prescribed in Sections 8 (*b*), (*c*) and (*d*).

(*c*) Test pieces shall be cut from the specimens as prescribed in Section 13 (*c*).

Procedure.

19. The effect of oil on the varnish shall be determined by immersing the specimens in transformer oil at a temperature of 100° C. (212° F.) for 48 hours and noting the effect on the varnish as indicated, for example, by wiping with a piece of dry white cloth.

NOTE.—Incipient disintegration of the surface of the varnish may sometimes be detected by examining the oil for turbidity. If a specimen of the oil filtered through filter paper can be distinguished from an unfiltered sample when the two samples are held in front of a strong light, the oil is turbid.

DRAINING TEST

(ALSO KNOWN AS "WORKING VISCOSITY" TEST)

Test Specimen. 20. A strip of bond paper 0.064 mm. (2.5 mils) in thickness, 10.2 cm. (4 in.) in width and 50.8 cm. (20 in.) in length, shall be immersed in the varnish at a room temperature of approximately 20° C. (68° F.) up to a line previously drawn across the paper a few inches from the top. The paper shall be withdrawn at a slow and uniform rate (about 38 cm. (15 in.) per minute), care being taken that the varnish is free from air bubbles. The specimen shall be permitted to drain thoroughly at room temperature while suspended in a vertical position. It shall then be dried or baked (according to the type of the varnish) until dry as determined in accordance with Section 7.

Measurements. 21. The thickness of the specimen in mils shall be measured at points 5.1 cm. (2 in.), 17.8 cm. (7 in.) and 30.5 cm. (12 in.), respectively, from the line to which the specimen was immersed.

Report. 22. The thickness of each film in mils at the three points specified in Section 21 shall be recorded. The difference between the thickness at the upper point (5.1 cm.) and that at the lower point (30.5 cm.) shall be taken as a measure of the variation in the film thickness caused by draining.

EVAPORATION TEST

Procedure. 23. One hundred cubic centimeters of the varnish shall be placed in a flat-bottom crystallizing dish approximately 75 mm. (2.95 in.) in diameter and 45 mm. (1.77 in.) in height. It shall be heated to a temperature of 100° F. (37.8° C.) ± 2° F. (1.1° C.) for a period of 7 hours, the sample being exposed to still air in the open room.

Evaporation. 24. The decrease in volume of the sample shall be taken as the evaporation, this decrease being determined by noting the amount of water or kerosine that must be added to fill the dish to the original level.

NOTE.—This test is relative only. That is, it is only suitable for comparing one varnish with another when the tests are made simultaneously under exactly the same conditions.

TEST FOR NON-VOLATILE MATTER

Procedure. 25. A portion of the sample shall be placed in a stoppered bottle or weighing pipette and weighed. About 1.5 g. of the sample shall be transferred to a weighed flat-bottom metal dish about 8 cm. (3.15 in.) in diameter, such as the cover of a friction-top tin can. The container shall again be weighed and the exact weight of the portion of the sample transferred to the weighed dish calculated by difference. The dish with its contents shall be heated for three hours in an oven maintained at 105 to 110° C. It shall then be weighed after cooling.

Non-Volatile Matter. 26. The ratio of the weight of the residue to that of the original sample expressed as a percentage shall be taken as the percentage of non-volatile matter in the varnish.

TEST FOR VOLATILE MATTER BY VOLUME

Scope. 27. This test is intended to determine the volume percentage of volatile matter (solvent) in a varnish, and to afford a means of arriving at the volume composition of the varnish with respect to volatile (solvent) and non-volatile (base) constituents.

Procedure. 28. (*a*) About 100 cc. of the varnish shall be distilled in accordance with the Standard Method of Test for Distillation of Gasoline, Naphtha, Kerosine, and Similar Petroleum Products (Serial Designation: D 86) of the American Society for Testing Materials.[1] The distillation shall be "qualitative" instead of "quantitative" as given in Section 9 of the Standard Method D 86; that is, it is not necessary to record the volume of distillate recovered, or the temperature of the initial boiling point or end point.

(*b*) The distillation shall be continued until a suitable end point indicates that all the volatile matter (solvent) has been distilled off.

NOTE.—In the distillation of varnishes the end point differs with the various types and compositions. In all cases, however, the rate of distillation slows down as the end point is approached; and, when the end point is reached, acrolein (formed in the decomposition of the varnish base) is evolved and may be detected by its characteristic odor.

In addition to the evolution of acrolein, the following phenomena are suitable indicators of end point:

(1) When the end point of the solvent is considerably lower than the initial boiling point of the base, the end point of the distillation is indicated by the temperature reaching a maximum and then starting to fall consistently.

(2) When the end point of the solvent and the initial boiling point of the base are too close, or overlap, the above temperature drop does not occur. The end point of the distillation is then indicated by a sudden foaming up of the residual base in the distillation flask; or, if the distillation has been accompanied by foaming, the end point is indicated by a breaking of surface tension with a consequent cessation of foaming.

Specific Gravity. 29. The specific gravity of the volatile matter (solvent) recovered by distillation shall be determined in accordance with the procedure described in Section 2.

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 378.

Volatile Matter by Weight. 30. The difference between 100 per cent and the percentage of non-volatile matter determined in Sections 25 and 26 shall be calculated and recorded as the percentage of volatile matter by weight.

Volatile Matter by Volume. 31. The percentage of volatile matter by volume shall be calculated from the formula:

$$x = \frac{AC}{B}$$

where

x = the percentage of volatile matter by volume;
A = the specific gravity of the original varnish, as determined in Section 2;
B = the specific gravity of the volatile matter (solvent) recovered by distillation, as determined in Section 29; and
C = the percentage of volatile matter by weight, as determined in Section 30.

Accuracy. 32. With proper care and attention to detail in making this test, differences occurring between different laboratories should not exceed 2 per cent for varnishes containing solvents which have end points not over 235° C. (455° F.), and should not exceed 4 per cent when the end point of the solvent is as high as 307.2° C. (585° F.).

DIELECTRIC STRENGTH OF VARNISH IN THE LIQUID STATE

Scope. 33. The purpose of the dielectric strength test of varnish in the liquid state is to insure that the varnish is free from moisture and foreign matter such as might come from unclean shipping containers.

Apparatus. 34. The apparatus shall be as described in Section 14 of the Standard Methods of Testing Molded Insulating Materials (Serial Designation: D 48) of the American Society for Testing Materials.[1] The test cup for holding the sample of varnish shall be made of a material having a suitable dielectric strength. It must be insoluble in and unattacked by mineral oil and gasoline and non-absorbent so far as moisture, mineral oil and gasoline are concerned. The electrodes in the test cup between which the sample is tested shall be circular disks of polished brass or copper, 1 in. in diameter and having square edges. The electrodes shall be mounted in the test cup having their axes horizontal and coincident, with a gap of 0.1 in. between their adjacent faces, and with top of electrodes about 33 mm. ($1\frac{1}{4}$ in.) below the top of the cup.

Procedure. 35. (*a*) The electrodes and the test cup shall be wiped clean with dry calendered tissue paper or with a clean dry chamois skin, and thoroughly rinsed with a suitable solvent such as dry benzol or redistilled carbon tetrachloride. The electrodes and test cup shall then be rinsed with some of the varnish to be tested.

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 785.

(*b*) The spacing of electrodes shall be checked with a standard round gage having a diameter of 0.100 in. and the electrodes then locked in position. Care shall be taken not to touch the electrodes with the gage or in any other manner after cleaning the electrodes and cup, so as to avoid any possible contamination.

(*c*) The temperature of the varnish when tested shall be the same as that of the room, which should be between 20 and 30° C. (68 and 86° F.).

(*d*) The sample of the varnish shall be shaken so that it will be thoroughly mixed before filling the test cup, the shaking shall be done gently to avoid the formation of bubbles.

(*e*) The cup shall be filled with varnish to a height of not less than 20 mm. (0.787 in.) above the top of the electrodes.

(*f*) The varnish shall be allowed to remain in the test cup until all air bubbles have disappeared.

(*g*) Voltage shall be applied and increased uniformly at the rate of approximately 3 kv. (r.m.s. value) per second until electrical breakdown occurs as indicated by a continuous discharge across the gap. (Occasional momentary discharges which do not result in a permanent arc may occur; these should be disregarded.)

(*h*) After the breakdown and before removing the varnish from the test cup, the electrode surfaces shall be rubbed thoroughly with dry calendered tissue paper wrapped around a knife blade to provide stiffness. The test cup shall then be emptied and immediately refilled with the next filling of varnish to be tested.

(*i*) Five fillings shall be tested in conformity with the above procedure and the last filling of the cup shall drain the sample container.

Variations in Results.

36. Differences as great as 15 per cent may occur between different laboratories in the results of this test. This is considered satisfactory in view of the purpose of the test.

Report.

37. The report shall include the following:

(*a*) The kilovolts (r.m.s. value) at each electrical breakdown;

(*b*) The average value of the 5 breakdowns in kilovolts; and

(*c*) The mean deviation from the average value expressed as a percentage of the average breakdown value.

APPENDIX

DIELECTRIC STRENGTH TESTS ON COPPER BASE

Where it is desired to make dielectric strength tests of solid films of varnish (as distinguished from the specimens prescribed in the methods, which are a combination of varnish and paper fibers), it is recommended that copper be used as the base as formerly required in the methods. The following are the directions for preparing and testing such specimens:

1. (*a*) Specimens are prepared by dipping pieces of thoroughly cleaned, smooth sheet copper or brass about 20 cm. (7.88 in.) square and about 0.127 mm. (0.005 in.) thick into the varnish which is at the consistency prescribed in Section 5 (*b*) of the methods.

(*b*) Each specimen is dipped twice, once in each direction, in order to give a more uniform thickness of coating. The specimen is dried after each dip in the same vertical position in which it was dipped.

(*c*) Specimens of air-drying varnish are dried in free air after each dip at a room temperature of approximately 20° C. (68° F.) for a period 600 per cent longer than that determined in accordance with Section 7 of the methods provided such period does not exceed 24 hours.

(*d*) Specimens of baking varnish are drained and then baked after each dip for a period 300 per cent greater than that determined in accordance with Section 7 provided such period does not exceed 24 hours.

(*e*) The final thickness of the film of varnish on each side of the specimen is between 0.044 mm. (0.0018 in.) and 0.052 mm. (0.002 in.).

2. (*a*) The dielectric strength of the two films of varnish is determined by applying alternating potential to two circular metal disks, 5.08 cm. (2.0 in.) in diameter and with edges rounded to a radius of 0.64 cm. (0.25 in.) which are placed in contact with the two sides of the specimen directly opposite each other and under a pressure of approximately 0.5 kg. (1.1 lb.). Starting at zero, the voltage is increased uniformly to breakdown at a rate of 0.5 kv. per second, except that if breakdown occurs at this rate in less than 40 seconds, the rate shall be decreased so that breakdown will not occur in less than 40 seconds. If the material fails at less than 5 kv., the minimum time shall be reduced from 40 seconds to 20 seconds. Ten such punctures are to be made at various points selected at random on each specimen. In each test the thickness of the films of varnish is to be determined as close to the point of puncture as practicable.

NOTE.—When necessary, in order to get ten punctures, additional specimens should be tested.

(*b*) The frequency of the test potential shall be not greater than 100 cycles per second, and each part of the testing apparatus shall have a continuous rating of not less than 2 kva. (preferably larger). The wave form shall be a sine curve as defined, and the voltage shall be measured by methods approved by the American Institute of Electrical Engineers.

(*c*) The voltage may be controlled by any approved method which does not distort the wave form beyond the limits prescribed above and which does not subdivide the voltage in steps greater than 500 volts. The apparatus shall comply with the Standards of the American Institute of Electrical Engineers.

3. The volts at puncture, the net thickness of insulation and the volts per mil of net thickness shall be reported for each of the ten tests together with the average maximum and minimum volts per mil.

TENTATIVE METHODS OF TESTING ELECTRICAL PORCELAIN[1]

Serial Designation: D 116 - 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1921; REVISED, 1924, 1926, 1927, 1928.

Scope.

1. These tests are intended to apply to porcelain which is to be used for electrical insulating purposes.

TENSILE STRENGTH

Apparatus.

2. Any standard testing machine of suitable capacity may be used providing the error in the loading range does not exceed 1 per cent.

Test Specimens.

3. (*a*) The test specimens for this test shall be of the form and dimensions shown in Fig. 1.

(*b*) For wet-process porcelain, the test specimens shall be made from a column obtained by forcing the batch mixture through a die. Sections of the column, after thorough drying, shall be formed to the required shape with due allowance for shrinkage. During the firing, care shall be taken to maintain the axis perfectly straight.

(*c*) For cast porcelain, the specimens shall be cast in molds of calcined gypsum (plaster of Paris) having the required shape, due allowance being made for all shrinkages. None of the material except the fins shall be removed from the specimen.

(*d*) For dry-process porcelain, the specimens shall be formed by pressure into the required shape in metal molds with due allowance for all shrinkages.

Mounting of Specimens.

4. (*a*) Suitable grips for holding the specimen shall be self-aligning and shall grip the specimen over sufficient area and in a manner not to cause pinching near the minimum section nor local compression at the smaller ends of the metal grips. Grips designed for the purpose and found satisfactory are shown in Fig. 2. In principle they are arranged like gimbals or a universal joint used for maintaining a mariner's compass in position. A yoke allows a ring to swing about

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[1] Criticisms of these Tentative Methods are solicited and should be directed to Mr. T. S. Taylor, Secretary of Committee D-9 on Electrical Insulating Materials, Bakelite Corporation, 230 Grove St., Bloomfield, N. J.

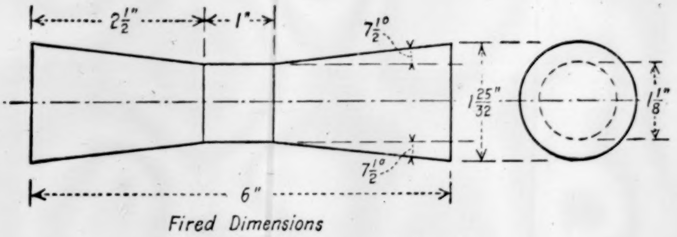
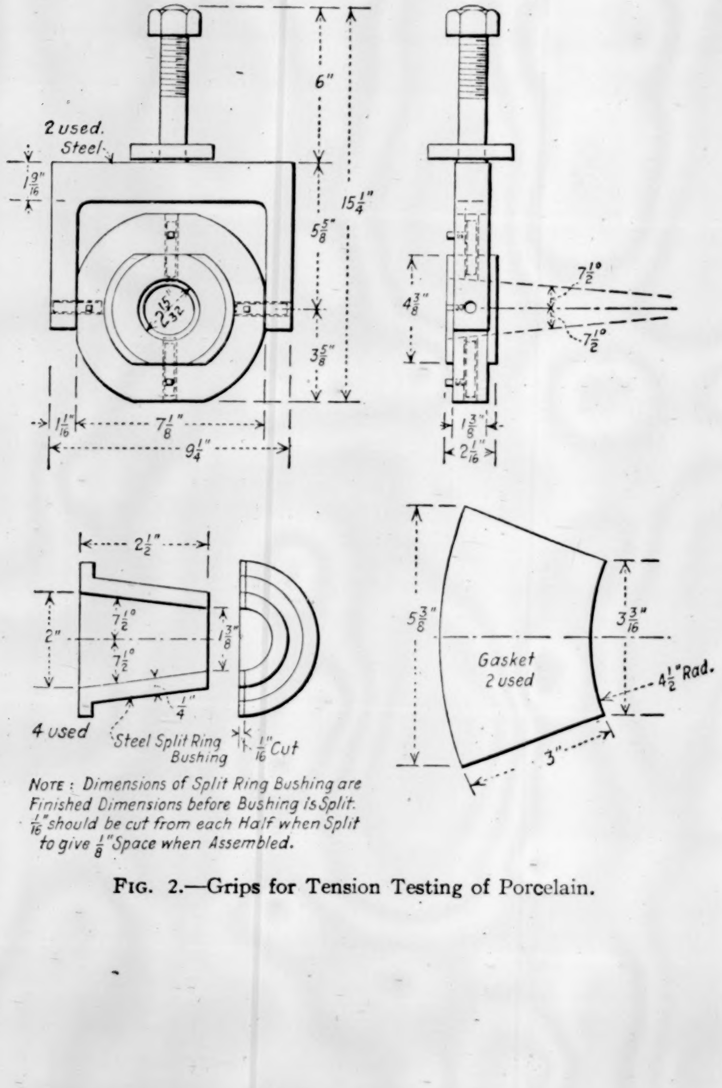

2½"
1"
7½°
1 25/32"
1⅛"
7½°
6"
Fired Dimensions

FIG. 1.—Test Specimen for Determining Tensile Strength of Porcelain.


6"
15¼"
2 used.
Steel
1 9/16"
5⅝"
2 15/32"
4⅜"
7½°
7½°
3⅝"
1 1/16"
7⅛"
9¼"
1⅜"
2 1/16"
2½"
2"
7½°
7½°
1⅜"
1/4"
4 used
Steel Split Ring Bushing
1/16" Cut
5⅜"
3 3/16"
Gasket
2 used
4½" Rad.
3"

NOTE: Dimensions of Split Ring Bushing are Finished Dimensions before Bushing is Split. 1/16" should be cut from each Half when Split to give 1/8" Space when Assembled.

FIG. 2.—Grips for Tension Testing of Porcelain.

a horizontal axis. A smaller ring is situated inside the first one but pivoted by means of pins in a plane perpendicular to the horizontal axis. The inner ring is conically shaped and holds the porcelain specimen in place with the aid of the split bushings. The two yokes are placed in the testing machine at right angles to each other.

(*b*) The test specimen shall be fitted with a compressible gasket around each conical end with the parallel edges nearly touching. Blotting paper or sheet lead $\frac{1}{32}$ in. thick has been found satisfactory. The gasket may be held in place, while assembling the test specimen in the grips, by a temporary clamp at the place of minimum section. After the specimen has been assembled in place ready for test, the temporary clamp shall be removed. The grips holding the test specimen in place in the testing machine are shown in Fig. 3. A disassembled view of the apparatus is shown in Fig. 4.

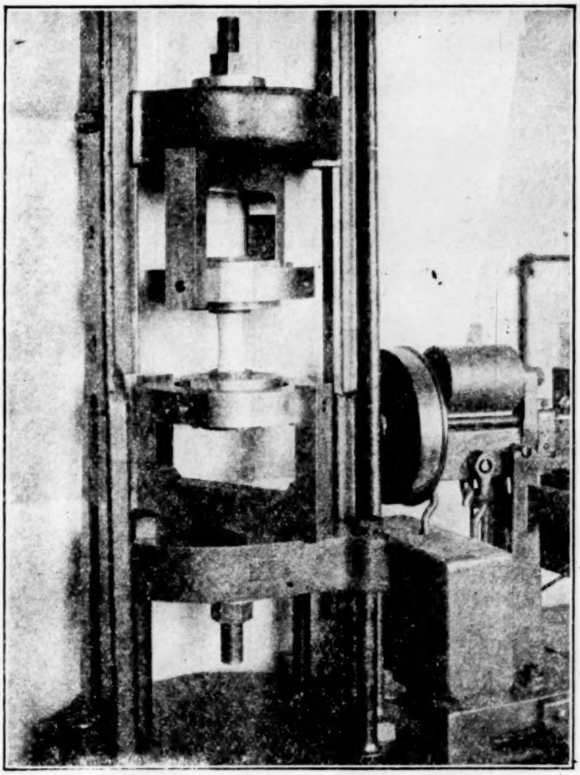


FIG. 3.—Grips and Test Specimens Assembled in Testing Machine in Tension Testing of Porcelain.

Procedure. 5. (*a*) Not less than five specimens shall be tested in the normal condition.

(*b*) The diameter of each specimen at the minimum section shall be measured with a micrometer graduated to 0.001 in. (0.025 mm.). The value of the diameter to be used in the calculation shall be the average of two measurements taken at right angles.

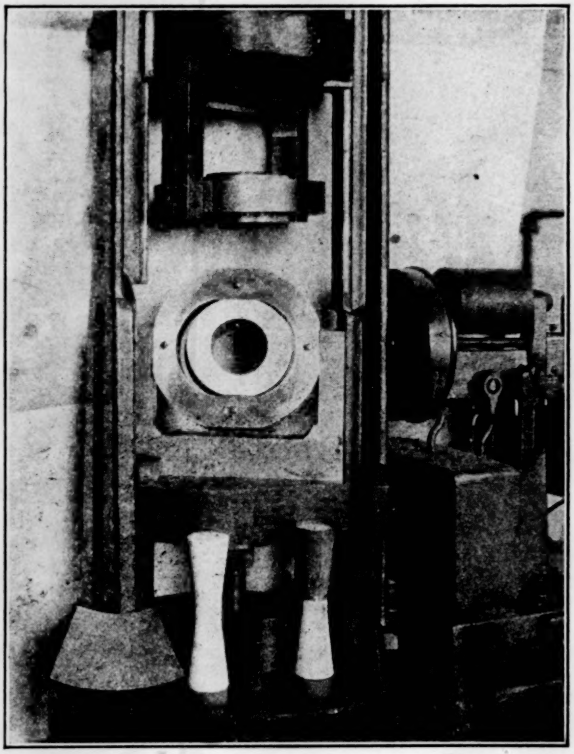


FIG. 4.—Apparatus for Tension Testing of Porcelain, Including Grips, Specimen, Split Ring and Blotting Paper Gasket.

(*c*) The speed of head of the testing machine shall be such that the load can be accurately weighed.

(*d*) The tests shall be made at a temperature of about 21° C. (70° F.).

(*e*) Results on specimens which do not break in the section of minimum cross-section shall be included, though the unit stress shall be calculated using the minimum cross-section. Any results whose deviation from the mean of the deviations is more than 3 times the mean of the deviations shall be discarded.

Report.

6. The report shall include the following:

(*a*) The breaking load of each specimen in pounds.

(*b*) The diameter of each specimen in inches at the place of break and at the minimum section.

(*c*) The tensile strength of each specimen in pounds per square inch.

(*d*) The average of the results given in Paragraph (*c*) and the percentage average deviation from the mean.

(*e*) A description of each fracture and the behavior of the material under load. The description of the fracture should tell whether the fractured area was totally or partially rough, and whether pin holes or other flaws were found.

NOTE.—An examination of the fracture of a normal specimen will show the entire area to consist of a very coarse granular surface, indicating that the entire area was subjected to tension and that the entire surface resisted it. In a specimen containing a pin hole or other flaw, the fracture will usually start near that flaw or pass through it. Part of the surface further away from the flaw will be granular, but the surface near the flaw will be much smoother. If the specimen is compressed at a narrow portion near one of the grips, the surface is again divided into two distinct areas, the area of tension and the area of shear, the latter radiating from the spot which was most under compression.

(*f*) The rate of application of the load.

(*g*) The name and rating of the machine used to make the tests.

(*h*) A curve sheet showing the tensile strength in pounds per square inch of each specimen, the first value being the lowest and each succeeding one the next higher.

COMPRESSIVE (CRUSHING) STRENGTH

Apparatus.

7. Any standard testing machine of suitable capacity may be used providing the error in the loading range does not exceed 1 per cent.

Test Specimens.

8. (*a*). The test specimens for this test shall be in the form of cylinders and shall be 1.125 in. (2.86 cm.) in length and 1.125 in. (2.86 cm.) in diameter.

(*b*) They shall be made as described in Section 3. The flat surfaces shall be made as smooth and parallel as possible before firing. After firing, the flat surfaces shall be ground smooth and parallel.

Procedure.

9. (*a*) Not less than five specimens shall be tested in the normal condition.

(*b*) A contact pad or cushion of blotting paper $\frac{1}{64}$ in. thick shall be placed between the upper and lower faces of the specimen and the self-aligning heads of the testing machine to equalize irregularities in the surfaces. Fresh cushions shall be used for each specimen.

(*c*) The diameter and length of each specimen shall be measured with a micrometer graduated to 0.001 in. (0.025 mm.). The value of the diameter to be used in the calculations shall be the average of two measurements taken at right angles.

(*d*) The speed of head of the testing machine shall be such that the load can be accurately weighed.

(*e*) The tests shall be made at a temperature of about 21° C. (70° F.).

Initial and Ultimate Failure.

10. Note shall be made of the load in pounds at initial failure but the value of the load in pounds at ultimate failure shall be determined and used in calculating the compressive (crushing) strength.

Report.

11. The report shall include the following:

(*a*) The load in pounds on each specimen at initial failure and the load in pounds at ultimate failure.

(*b*) The diameter and length of each specimen in inches.

(*c*) The compressive (crushing) strength of each specimen in pounds per square inch.

(*d*) The average of the results given in Paragraph (*c*) and the percentage average deviation from the mean.

(*e*) The behavior of the material under load.

(*f*) The rate of application of the load.

(*g*) The name and rating of the machine used to make the tests.

(*h*) A curve sheet showing the compressive strength in pounds per square inch of each specimen, the first value being the lowest and each succeeding one the next higher.

TRANSVERSE STRENGTH

Apparatus.

12. Any standard testing machine of suitable capacity may be used.

Test Specimens.

13. (*a*) The test specimens for the transverse strength test shall be in the form of cylinders and shall be 6 in. (15.2 cm.) in length and 1.125 in. (2.86 cm.) in diameter.

(*b*) They shall be made as described in Section 3.

Mounting of Specimens.

14. The specimen shall be supported on two steel wedge-shaped blocks with supporting edge rounded to 0.125 in. (3.175 mm.) radius. The supports shall be 5 in. (127 mm.) apart and the specimen shall be laid upon them with ½ in. (12.7 mm.) overlap at each end. The load shall be applied on top of the specimen at right angles to the specimen and midway between the supports by means of a wedge-shaped pressure piece (angle 45 deg.), the edge of which is rounded on a 0.125 in. (3.175 mm.) radius.

Method. 15. (*a*) Not less than five specimens shall be tested in the normal condition.

(*b*) The diameter of each specimen shall be measured with a micrometer graduated to 0.001 in. (0.025 mm.). The value of the diameter to be used in the calculations shall be the average of two measurements taken at right angles at the middle of the specimen.

(*c*) The load shall be applied at that constant rate of speed which will permit the beam to be kept well balanced at all loads.

(*d*) The tests shall be made at a temperature of about 21° C. (70° F.).

Modulus of Rupture. 16. The modulus of rupture shall be calculated for each specimen as follows:

$$M = \frac{8\,PL}{\pi\,d^3}$$

where M = modulus of rupture;
P = load in pounds at rupture;
L = distance between supports in inches;
d = diameter of specimen in inches;
π = 3.1416.

Report. 17. The report shall include the following:

(*a*) The breaking load of each specimen in pounds.

(*b*) The diameter and length of each specimen in inches.

(*c*) The modulus of rupture for each specimen as calculated in Section 16.

(*d*) The average of the results given in Paragraph (*a*) and the percentage average deviation from the mean.

(*e*) A description of each fracture and the behavior of the material under load.

(*f*) The rate of application of the load.

(*g*) The name and rating of the machine used to make the tests.

(*h*) A curve sheet showing the transverse strength (modulus of rupture) for each specimen, the first value being the lowest and each succeeding one the next higher.

RESISTANCE TO IMPACT

Resistance to Impact. 18. Resistance to impact shall be determined in accordance with the Tentative Methods of Testing Insulating Materials for Resistance to Impact (Serial Designation: D 256 - 28 T) of the American Society for Testing Materials,[1] using the "Simple Beam Method."

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[1] See p. 1021.

DIELECTRIC STRENGTH

Apparatus. 19. The apparatus shall be as described in Section 14 of the Standard Methods of Testing Molded Insulating Materials (Serial Designation: D 48) of the American Society for Testing Materials.[1]

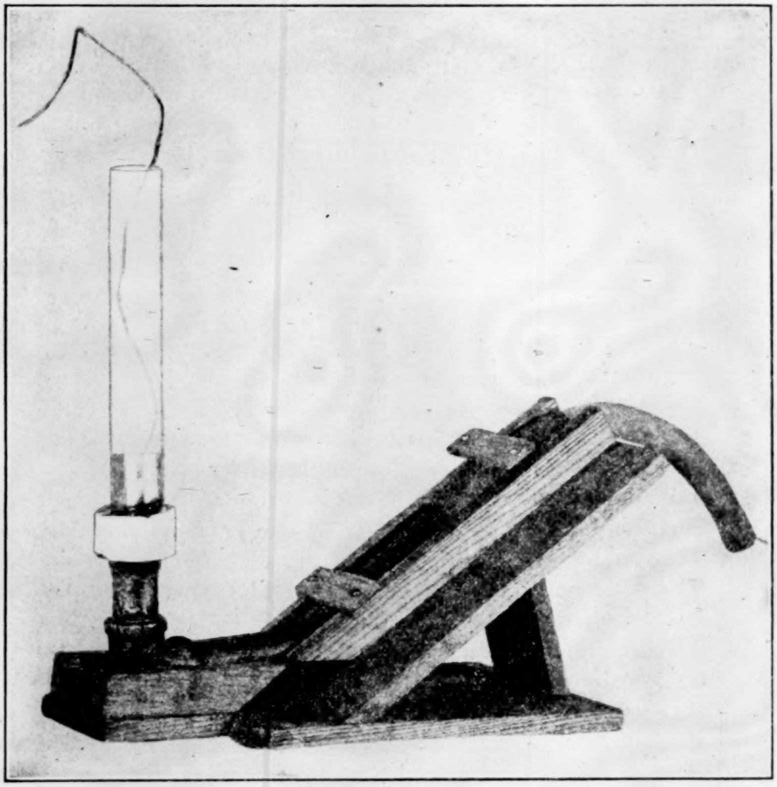

FIG. 5.—Suggested Means for Holding Porcelain Dielectric Strength Test Specimen.

Test Specimen. 20. The specimen shall be a disk approximately 2 in. in diameter, the flat sides being made plane and parallel. The thickness of the specimen shall be 0.250 in. (6.35 mm.), 0.4 in. (10.16 mm.), 0.75 in. (19.05 mm.), or 1.0 in. (25.4 mm.). The thickness shall be within ± 10 per cent of these values.

NOTE.—The specimen tested should be of a thickness comparable to that of the finished porcelain product.

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 785

Procedure. 21. (*a*) The specimen shall be tested between metallic electrodes 0.75 in. (19.05 mm.) in diameter, placed exactly opposite each other.

NOTE.—A suggested means for holding the specimen, using mercury electrodes, is shown in Fig. 5. This consists of a metal tube supported in a frame. The specimen is affixed to the metal tube using ordinary sealing wax, and a short glass tube is similarly affixed to the upper surface of the specimen.

In applying the sealing wax, one end of the tube is dipped about ⅜ in. (9.5 mm.) into a bath of molten wax. Upon removal, it is immediately pressed into place on the specimen and allowed to cool to room temperature. (If a film of wax covers the tube it should be broken before placing the tube on the specimen.) In order more thoroughly to smooth out the wax and seal the tube, the wax seal may be softened slightly with a fine moderate flame. The test specimen should never be heated when affixing the tubes, as the heat may set up strains in the porcelain specimen that will materially affect its properties.

Mercury is introduced into both tubes, avoiding entrapped air, and lead wires are placed in the mercury. The entire set-up is immersed in high-grade mineral insulating oil. It is best to have the ends of the tubes projecting above the oil level.

(*b*) The testing voltage shall be raised at a constant rate of approximately 1000 volts per second until puncture occurs.

(*c*) Not less than five specimens shall be punctured in their normal condition at a normal room temperature of about 20° C. (68° F.).

Report. 22. The report shall include the following:

(*a*) The breakdown voltage for each specimen in kilovolts;

(*b*) The thickness of each specimen in mils at point of break;

(*c*) The dielectric strength in volts per mil calculated from the values reported in Paragraphs (*a*) and (*b*);

(*d*) The average breakdown voltage, the average thickness of the specimen at break, and the average dielectric strength in volts per mil for the specimens tested.

RESISTANCE TO THERMAL CHANGE

(*A*) *Porcelain for Transmission Line Insulators.*

Apparatus. 23. The apparatus shall consist of a hot water bath maintained at a temperature of 100° C. (212° F.) and an ice water bath maintained at 0° C. (32° F.).

Specimens. 24. The test specimens shall be as described in Section 13.

Procedure. 25. (*a*) The test specimen shall be immersed in the ice water bath for ten minutes and then transferred as quickly as possible to the hot water bath, and allowed to remain there for ten minutes. The specimen shall be transferred back to the cold water and the cycles continued until the specimen breaks.

(*b*) Not less than five specimens shall be tested.

Report. 26. Report the number of cycles necessary to cause fracture of each test specimen.

(*B*) *Porcelain for Spark Plugs and Heating Devices.*

Apparatus. 27. A furnace in which a temperature of 900° C. (1652° F.) can be obtained and any suitable testing machine for determining the transverse strength of small beams may be used.

Specimens. 28. The test specimens shall be as described in Section 13.

Method. 29. (*a*) One-half of not less than 12 specimens shall be taken and placed in the furnace. The rate of heating shall be so adjusted that the temperature reaches 900° C. (1652° F.) in two hours. The furnace shall then be allowed to cool at such a rate that room temperature is reached in four hours.

(*b*) All specimens for transverse strength shall be tested by placing them on supports 5 in. apart and loading them at the center.

Report. 30. The report shall include the following:

(*a*) The load in pounds or kilograms required to break each specimen not subjected to heat treatment, together with the average.

(*b*) The load required to break each specimen that was subjected to heat treatment, together with the average.

(*c*) The percentage loss of strength due to heat treatment calculated from the two averages.

POROSITY

(*A*) *Water Absorption.*

Apparatus. 31. Any good chemical balance, a beaker of distilled water at normal room temperature of about 20° C. (68° F.) and an oven of any standard make capable of maintaining a uniform temperature at the desired point within ± 5° C. shall be provided.

Specimens. 32. A single piece of porcelain shall be used weighing from 30 to 50 g. and with at least 50 per cent of the surface newly fractured.

Procedure. 33. The specimen shall be dried for 24 hours at 120° C. (248° F.), cooled in a desiccator and weighed. The specimen shall then be totally submerged in the distilled water at room temperature (about 20° C.) and allowed to remain submerged for 100 hours. The water shall be boiled for approximately one hour during the first, twenty-fifth, forty-ninth and seventy-third hours. The specimen shall be removed at the end of the 100-hour period, the surface moisture carefully dried off with a clean, dry cloth and the specimen weighed.

Report. 34. The report shall include the following:

(*a*) The original weight of the specimen;

(*b*) The dry weight of the specimen;

(*c*) The dry weight of the specimen after immersion for 100 hours;

(*d*) The percentage of moisture content in each specimen as received and the percentage of moisture absorbed during 100 hours, taking the dry weight as 100 per cent, and the average where more than one specimen is tested.

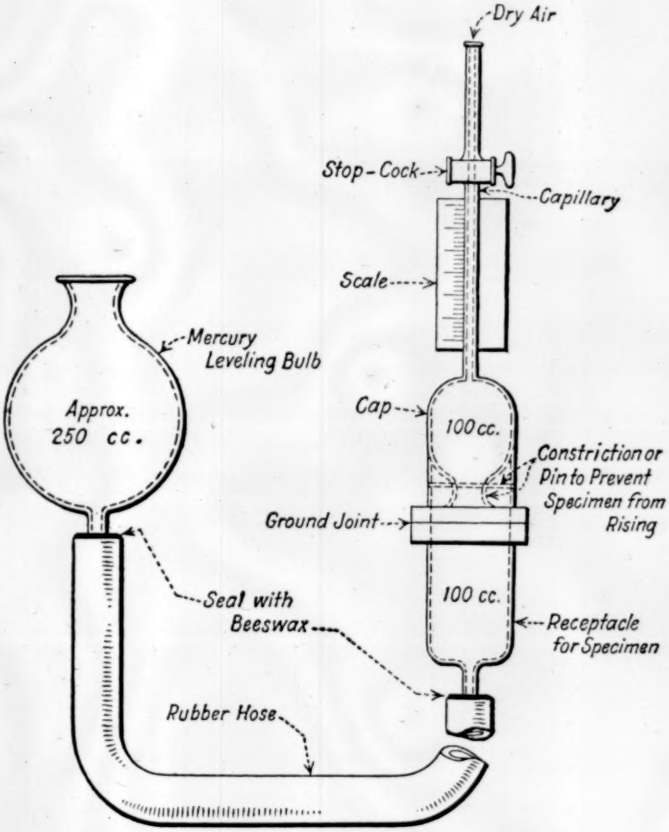
Dry Air
Stop-Cock
Capillary
Scale
Mercury Leveling Bulb
Approx. 250 cc.
Cap
100 cc.
Constriction or Pin to Prevent Specimen from Rising
Ground Joint
Seal with Beeswax
100 cc.
Receptacle for Specimen
Rubber Hose

FIG. 6.—Diagrammatic Sketch of McLeod Porosimeter.

(*B*) *Pore Volume*

35. The pore volume of porcelain shall be determined by measuring (at atmospheric pressure) the volume of air contained in a sample of porcelain of known volume. **Pore Volume.**

36. Any suitable apparatus based on the laws of gas expansion, which will accomplish the measurement called for in Section 35 may be used. **Apparatus.**

The McLeod gage type of porosimeter is especially adaptable to this determination. This apparatus consists of a receptacle and cap fitted together by a ground air-tight joint. The cap is surmounted by a calibrated capillary tube and stop-cock. The specimen is placed in the receptacle and prevented from rising into the cap by means of a constriction or pin. The receptacle is connected by a glass or metal pipe at the bottom to a heavy rubber hose which in turn is connected to a glass leveling bulb. The total volume of the specimen receptacle and cap should be approximately 200 cc. Figure 6 shows a diagrammatic sketch of a McLeod gage-type porosimeter.

NOTE.—Suitable porosimeters of the McLeod gage type are: (1) glass apparatus of Washburn and Bunting;[1] (2) metal apparatus of Navias.[2]

Volume and Length of Capillary.—For porcelain of low-pore volume it is necessary to use a capillary of small diameter to read the volume of accumulated air accurately. Thus, for porcelain up to 1 per cent pore volume the effective volume of the capillary must be at least 0.5 cc. (for a specimen of 50 cc. volume). For porcelain having a higher pore volume than 1 per cent, either a longer capillary or a capillary of larger diameter is required.

Atmospheric Conditions.—It is essential that the determination be made using dry air. This may be provided by any suitable means.

Test Specimen.

37. The test specimen shall consist of two or more pieces of porcelain having a total volume of not less than 50 cc. At least 50 per cent of the surface of the parts used shall be newly fractured.

Procedure.

38. (*a*) The following procedure is based on the use of a McLeod gage type of porosimeter:

(*b*) The fractured pieces of porcelain shall be placed in the receptacle, the ground joint greased, and the cap secured in position so that the apparatus is air-tight.

(*c*) Before making determinations, any moisture entrapped on the inner surfaces of the porosimeter or which may be on the test specimen shall be removed. To do this, the leveling bulb shall be raised until the mercury in the capillary is above the stop-cock. The stop-cock shall then be closed and the leveling bulb lowered so that the test specimen is subjected to a vacuum for at least one minute. Any moisture inside the porosimeter then vaporizes and by again raising the leveling bulb the gas is collected in the capillary and shall be finally expelled by opening the stop-cock.

(*d*) Immediately after removing the moisture the leveling bulb shall be lowered, exposing the test specimen to the air for at least one minute. The leveling bulb shall again be raised until the mercury in the capillary is above the stop-cock. The stop-cock shall then be closed and the leveling bulb lowered so as to expose all the specimen to the vacuum for at least one minute. The air contained in the porcelain then expands into the evacuated space around and above the porcelain. The mercury bulb shall then be raised again and the air collected in the capillary tube. When the mercury surface in the leveling bulb is on a level with the mercury meniscus in the capillary the accumulated air in the capillary is at atmospheric pressure and its volume, v, shall be read. This shall be considered to be the pore volume.

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[1] **Washburn and Bunting**, *Journal*, Am. Ceramic Soc., Vol. 5, pp. 528–535 (1922).

[2] **Navias**, *Journal*, Am. Ceramic Soc., Vol. 8, pp. 816–821 (1925).

(*e*) Several determinations of the pore volume should immediately be made as described in Paragraph (*d*). The values of pore volume thus obtained should be practically equal, and their average may be taken as the pore volume of the specimen, v. Lack of agreement among these values may be traced to leaks or moisture in the apparatus.

NOTE.—To test for leaks in the apparatus: After taking a reading, expel all gas from the apparatus. Close the stop-cock. Raise and lower the leveling bulb several times. The level of the mercury in the capillary should rise to the stop-cock when the leveling bulb is raised.

(*f*) The total volume V, of the pieces of each specimen shall be obtained by any suitable method, measuring to the nearest 0.2 cc.

(*g*) Not less than five specimens shall be tested.

Percentage of Pore Volume.

39. The percentage of pore volume shall be calculated as the volume of gas contained in the total volume of porcelain:

$$\text{Percentage of pore volume} = \frac{v \times 100}{V}$$

where V = total volume of test specimen as determined in Section 38 (*f*); and
v = the pore volume as determined in Sections 38 (*d*) and (*e*).

Report.

40. The report shall include the following:

(*a*) The percentage of pore volume of each specimen, the average of these values, and the percentage average deviation from the mean;

(*b*) The total volume of each test specimen;

(*c*) The name and type of the apparatus used;

(*d*) The total volume of the specimen receptacle.

TENTATIVE METHODS OF TESTING UNTREATED INSULATING PAPER[1]

Serial Designation: D 202 – 28 T

This is a **Tentative Standard**, published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1924; REVISED, 1925, 1926, 1927, 1928.

Scope. 1. These methods apply to untreated paper which is to be used as an electrical insulator or as a constituent of a composite material used for electrical insulating purposes.

SAMPLING

Sampling. 2. (*a*) From shipments consisting of rolls, a sample of at least 1 sq. yd. in area, cut across the entire width of the roll, shall be taken from every tenth roll in the shipment. From other shipments such as sheets or pads of tape, samples of equivalent area shall be taken in such a manner as to be equally representative of the shipment. In no case shall less than three samples be taken.

NOTE.—It is recommended that several turns of paper from each roll sampled be torn off and discarded before the samples are taken.

(*b*) The tests for physical properties shall be made upon each sample.

(*c*) The tests for acidity, moisture content, size,[2] ash and for identification of fibers[2] shall be made in duplicate upon portions taken from a composite sample. This composite sample shall be made up of a sufficient number of small pieces, each of approximately 6.5 sq.cm. (1 sq. in.) in area taken in nearly equal amounts from each of the samples taken in accordance with Paragraph (*a*).

(*d*) The required number of samples shall be taken at equal intervals across the sheet, the two end samples being taken at the edges of the sheet after removing any damaged paper. When it is not possible to secure the required number of specimens in this manner in going once across the sheet, the selection across the sheet shall be repeated as many times as necessary until the required number of specimens is secured.

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[1] Criticisms of these Tentative Methods are solicited and should be directed to Mr. T. S. Taylor, Secretary of Committee D-9 on Electrical Insulating Materials, Bakelite Corporation, 230 Grove St., Bloomfield, N. J.

[2] The tests for size, identification of fibers, and folding endurance do not appear in these methods but will be included as soon as the tests are developed by the committee.

CONDITIONING SAMPLES

Conditioning. 3. Samples shall be conditioned in air maintained at a relative humidity between 60 and 65 per cent as measured with a sling psychrometer or its equivalent. The temperature of the air shall be maintained as constant as possible at some temperature between the limits of 20 and 30° C. (68 and 86° F.). The samples should remain in the conditioned air for not less than 4 hours prior to the tests and should be supported so as to allow a free circulation around each sample. The following physical tests shall be made in the conditioned air: tensile breaking strength, tearing strength, bursting strength, folding endurance,[1] air resistance, and thickness.

MOISTURE CONTENT

Apparatus. 4. A weighing bottle, evaporating dish, thermometer, constant-temperature oven, chemical balance and desiccator are necessary for the test. The weighing bottle should be of convenient size, about 65 mm. (2.56 in.) in height and 45 mm. (1.77 in.) in diameter with a wide mouth provided with a ground-glass stopper. The chemical balance should be sensitive to 0.1 mg.

Specimen 5. The moisture content figure is used to calculate the percentage of acidity, size, and ash of the paper to the bone-dry basis. It shall be determined on 2 to 5-g. samples selected in accordance with Section 2 (*c*).

If the moisture content of the paper as received at the purchaser's works is desired or at any other stated time, it shall be made on the sample taken at the definitely stated time by cutting small pieces of approximately 6.5 sq. cm. (1 sq. in.) in area from the required number of rolls or pads of tape in accordance with Section 2 (*a*) and immediately placed into an air-tight container.

NOTE.—Since paper adjusts itself, as regards moisture content, to the humidity of the surrounding atmosphere in a very short time (2 or 3 minutes), special care must be exercised to transfer rapidly the sample from the roll or bundle to the container and from the container to the weighing bottle.

Procedure. 6. The sample before drying shall be weighed in the tared bottle with the stopper in place. The bottle shall then be placed in the oven at 100 to 105° C. (212 to 221° F.), the stopper removed and laid alongside of the bottle and the contents transferred to the drying dish. After one hour, while still in the oven, the sample shall be replaced in the weighing bottle, and the bottle stoppered and transferred to the desiccator. The stopper should be removed while the bottle cools. When the specimen and the bottle have cooled to room temperature, the stopper shall be replaced and the bottle with its contents weighed. This process shall be repeated at intervals of one hour until the difference in weight between two successive weighings is not more than 0.2 per cent of the weight of the specimen.

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[1] The tests for size, identification of fibers, and folding endurance do not appear in these methods but will be included as soon as the tests are developed by the committee.

NOTE.—The weighing bottle or sample should not be touched with the fingers during this test.

Report. 7. The moisture content shall be expressed:

(*a*) as a percentage of the weight of the dry sample, and

(*b*) as a percentage of the weight of the undried sample.

THICKNESS

Apparatus. 8. A micrometer of the spring actuated, dial type shall be used. The plunger shall be capable of being raised by the application of an upward pressure to it. The plunger surface shall be circular in shape and 12.7 mm. (0.50 in.) in diameter. The anvil surface shall be plane and circular in shape, the diameter of which shall be not less than 12.7 mm. (0.50 in.). It shall be centered with respect to the plunger surface.

In addition to these requirements, the instrument shall conform to the following:

(*a*) The pressure applied to the plunger necessary to move the pointer from zero toward a positive reading shall be not greater than 1135 g. (40 oz.).

(*b*) The pressure applied to the plunger necessary to just prevent movement of the pointer from zero toward a lower reading shall be not less than 455 g. (16 oz.).

(*c*) The diameter of the dial shall be approximately 15 cm. (6 in.) and shall be graduated preferably in divisions indicating a thickness of 0.0127 mm. (0.0005 in.) and in no case greater than 0.0254 mm. (0.001 in.). Graduations indicating a thickness of 0.0254 mm. (0.001 in.) shall be at least 3 mm. (0.12 in.) apart.

(*d*) Measurements made on standard steel thickness gages shall be within the following tolerances:

INTERVALS	PERMISSIBLE DEVIATION OF READING FROM ACTUAL THICKNESS OF STANDARD STEEL GAGE
0 to 0.25 mm. (0 to 0.01 in.) incl.	±0.0025 mm. (0.0001 in.)
Over 0.25 mm. to 1.02 mm. (0.01 in. to 0.04 in.) incl.	±0.0051 mm. (0.0002 in.)
Over 1.02 mm. to 3.05 mm. (0.04 in. to 0.12 in.) incl.	±0.0102 mm. (0.0004 in.)

(*e*) Convenient means shall be provided for setting the pointer to the zero position.

(*f*) The micrometer shall be tested periodically as outlined above and if it does not conform to these requirements its mechanism should be readjusted.

Specimens. 9. Specimens shall consist of the original samples obtained in accordance with Section 2 (*a*).

Methods. 10. At least five readings shall be taken at regular intervals across the entire width of each specimen. When measuring paper less than 0.05 mm. (0.002 in.) in thickness, a sufficient number of layers to give a reading on the scale of not less than 0.13 mm. (0.005 in.) shall be used.

In making measurements the plunger shall be raised to a point where its lower surface is from 0.45 to 0.55 mm. above the surface of the paper specimen lying in contact with the surface of the fixed anvil. The plunger shall be dropped from this height on the paper without retarding its speed of descent. When the thickness is read, care shall be taken not to touch the instrument.

Report. 11. The average, maximum and minimum thicknesses obtained on each specimen shall be reported.

TENSILE BREAKING STRENGTH

Apparatus. 12. (*a*) A testing machine of the dead-weight pendulum type suitably designed for testing paper shall be used. The machine shall preferably be power driven.

(*b*) The capacity of the machine shall not exceed 113 kg. (250 lb.).

(*c*) The machine shall be graduated to read 1 lb. or 1 kg. or less per scale division for testing paper breaking at 22.7 kg. (50 lb.) or over, and to 0.5 lb. or 0.5 kg. or less for testing paper breaking under 22.7 kg. (50 lb.).

Specimens. 13. From each of the samples selected in accordance with Section 2 (*a*), specimens shall be cut at least ten in the machine direction and if practicable, ten in the cross-machine direction. The specimens shall not exceed 2.54 cm. (1 in.) in width and shall be 25.4 cm. (10 in.) in length with clean-cut edges.

Procedure. 14. (*a*) The ratio of the clearance distance between jaws to the width of the specimen shall be not less than 5:1 nor more than 10:1.

(*b*) The rate of travel of the movable jaw shall be constant. It shall preferably be 30.5 cm. (12 in.) per minute, but it may be within the limits of 28 cm. (11 in.) and 33 cm. (13 in.) per minute provided it is constant.

(*c*) All readings obtained when the paper breaks at or in the jaws shall be rejected.

Report. 15. (*a*) The results of the machine-direction specimens and the cross-machine-direction specimens shall be reported separately.

(*b*) The results shall be reported in kilograms or pounds together with the width of the specimen in centimeters or inches and also the average thickness.

(*c*) The maximum, minimum, and average breaking load shall be reported for the machine direction and the cross-machine direction.

TEARING STRENGTH

Apparatus. 16. The testing machine shall be of the pendulum impulse type so designed as to produce a tear approximately 4.2 cm. (1.66 in.) long. The knife mounted on the machine to cut the slit for the tear shall be maintained sharp.

Specimen. 17. The specimens shall be taken from the original samples obtained in accordance with Section 2 (*b*) and shall be cut 6.3 cm. (2.5 in.) in width and at least 6.3 cm. (2.5 in.) in length. Enough specimens shall be cut so that at least five readings in the machine direction and five readings in the cross-direction, if possible, can be obtained for each original sample.

Method. 18. Enough paper shall be torn so that the readings on the machine shall be not less than 10 nor more than 20 g., unless one paper alone yields a reading greater than 20 g., in which case only one paper shall be torn at one time. The specimens shall be so arranged that an equal number of tears originating from opposite edges of the specimens will be produced. Readings obtained when a tear deviates more than 6.3 mm. (0.25 in.) from a straight line, shall be rejected. The readings obtained shall be multiplied by the instrument constant corresponding to the number of sheets torn.

Report. 19. (*a*) The tearing strengths obtained on the machine-direction specimens and on the cross-direction specimens shall be reported separately in grams.

(*b*) The average, the maximum, and the minimum tearing strengths shall be reported for the machine-direction specimens. If possible, similar results shall be reported for the cross-direction specimens.

BURSTING STRENGTH

Apparatus. 20. The testing machine shall have a circular flexible diaphragm 6.44 sq. cm. (1 sq. in.) in area. The pressure chamber shall be filled with glycerin or other suitable pressure medium and shall contain no air spaces. The test specimen shall be held in position over the diaphragm in a clamp having a circular hole approximately 6.44 sq. cm. (1 sq. in.) in area so that the diaphragm will force the paper into the hole when pressure is applied under the diaphragm. The pressure exerted on the diaphragm shall be indicated on a dial, graduated to at least 0.23 kg. (0.5 lb.) for papers giving bursting strengths 18 kg. (40 lb.) or under. A dial graduated 0.45 kg. (1 lb.) may be used in testing papers which give higher bursting strengths. The machine may be either hand-operated or power-driven, the latter being preferable.

Specimen. 21. If practicable, the specimen shall be so cut from the stock as to permit ten bursting tests on a line across the sheet or roll.

Procedure. 22. Ten bursts shall be made. The testing machine shall be driven at a uniform speed of 120 r.p.m. until the specimen bursts.

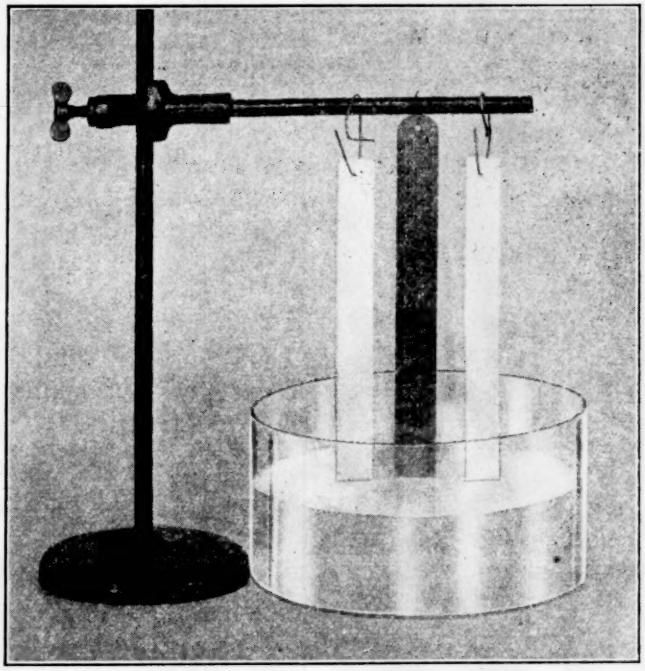

FIG. 1.—Apparatus for Absorption Test.

Report. 23. The report shall include the average, the maximum, and the minimum results obtained.

ABSORPTION

(RISE OF WATER)

Apparatus. 24. A suitable container and support for specimens and scale is shown in Fig. 1.

Specimens. 25. Ten strips 2.5 cm. (1 in.) in width and at least 12.5 cm. (5 in.) in length shall be cut from the samples obtained in accordance with Section 2 (*a*), five being cut parallel with the machine direction of the paper and five being cut parallel with the cross-direction of the paper.

Procedure. 26. The specimens shall be suspended vertically with one end dipping 3.2 mm. (0.125 in.) in distilled water at room temperature.

After five minutes of suspension, the rise of the water in the paper above the water level shall be noted. The rise may be measured by reading directly from the scale the height of absorption.

Report. 27. The rise of water shall be reported in millimeters to the nearest 3 mm. or in inches to the nearest $\frac{1}{8}$ in.

MIL WEIGHT PER REAM
(APPARENT DENSITY)

Apparatus. 28. A scale, sharp knife, chemical balance and weighing bottle are necessary for the test.

Specimens. 29. Duplicate specimens shall be taken from as widely separated portions as possible from each of the samples obtained in accordance with Section 2 (*a*) and conditioned in accordance with Section 3.

Procedure. 30. (*a*) Each specimen while in the conditioned atmosphere (see Section 3) shall be cut accurately to any convenient size, for example, 232.3 sq. cm. (36 sq. in.) in area, and accurately weighed. Specimens of sufficient size to weigh at least from 3 to 5 g. (0.11 to 0.18 oz.) should be taken. If it is not possible to do the weighing in the conditioned atmosphere, the specimen shall be placed in a weighing bottle and tightly stoppered with a ground glass stopper before being removed from the conditioned atmosphere. The thickness of each specimen shall be determined in accordance with Section 10.

(*b*) *Mil Weight per Ream of Any Size.*—The mil (or point) weight in pounds per ream of any size may be calculated from the following formula:

$$W = 0.002205\,\frac{mSN}{ta}$$

where m = the weight of the specimen expressed in grams;

t = the average thickness of the specimen expressed in mils (thousandths of an inch);

a = the area of the specimen expressed in square inches;

S = the area of one sheet in the basic ream expressed in square inches;

N = the number of sheets in the ream.

NOTE.—0.002205 is contracted from 0.00220462.

NOTE.—The following formulas may be used to calculate the mil weight in pounds per ream for reams of particular sizes, provided a specimen of exactly 232.3 sq. cm. (36 sq. in.) is used:

Ream of 24 by 36 in., 480 sheets.

$$W = 25.40 \frac{m}{t}$$

where m = the weight of specimen expressed in grams;

t = the average thickness of the specimen in mils (thousandths of an inch).

25.40 is contracted from 25.3972224.

Ream of 24 by 36 in., 500 sheets.

$$W = 26.45 \frac{m}{t}$$

where m and t are the same as above and 26.45 is contracted from 26.45544.

NOTE.—The ream weight may be obtained from the above formulas by omitting the thickness "t".

(*c*) *Weight per Unit Volume.*—The weight in pounds per cubic foot (density) may be calculated from the following formula:

$$D = 3810 \frac{m}{ta}$$

where m = the weight of the specimen expressed in grams.

t = the average thickness of the specimen expressed in mils (thousandths of an inch).

a = the area of the specimen expressed in square inches.

NOTE.—3810 is contracted from 3809.58336.

NOTE.—To convert weight in pounds per cubic foot to mil weight in pounds per ream of 24 by 36 in., 480 sheets, multiply by 0.24; to convert to mil weight in pounds per ream of 24 by 36 in., 500 sheets, multiply by 0.25.

Report. 31. The weight in pounds per cubic foot or the mil weight per ream shall be reported. The size of the ream must be given when the mil weight per ream is reported.

AIR RESISTANCE

Apparatus. 32. (*a*) The instrument shall consist of two aluminum open-top cylinders, one of which is inverted and slides into the other which is fixed. The movable cylinder shall be provided with a circular aperture in the closed end and a flat ring clamp for holding the paper specimen across this aperture.

(*b*) The fixed cylinder shall be 25.4 cm. (10 in.) in height and shall have an external diameter of 8.60 cm. (3.38 in.) and an internal diameter of 8.25 cm. (3.25 in.). Four slender bars, each 18.5 cm. (7.3 in.) long, 3 mm. (0.12 in.) wide and approximately 1.5 mm. (0.06 in.) thick shall be mounted vertically and equi-distantly on the inner surface of the fixed cylinder to act as guide tracks for the movable cylinder. The movable cylinder shall be graduated in units of 50 cc. and shall have a total range of 350 cc. It shall be 25.4 cm. (10 in.)

high and shall have an external diameter of 7.62 cm. (3.00 in.) and an internal diameter of 7.35 cm. (2.90 in.). It shall weigh, including the flat ring clamp and the two knurled nuts, 567 g. (20 oz.) ±5 g. (0.18 oz.). The movable cylinder and the flat ring clamp shall have a concentric circular aperture of 6.44 sq. cm. (1.00 sq. in.) in area. When this aperture is too large for the specimen a similar movable cylinder and flat ring clamp having a concentric circular aperture of 1.61 sq. cm. (0.25 sq. in.) in area shall be used.

NOTE.—Results obtained with apertures of different areas are not directly proportional to the areas of the apertures. The proportionality factor must be determined by experiment.

Specimen. 33. The specimens shall be not less than 3.5 cm. (1.36 in.) nor more than 5.1 cm. (2.0 in.) in width cut from the original samples, taken according to Section 2 (*a*) and shall be as long as the width of the original roll of paper. If the specimens are selected from pads of tape they shall be not less than 2.1 cm. (0.81 in.) nor more than 5.1 cm. (2.0 in.) wide and at least 30 cm. (12 in.) long. There shall be as many specimens as there are original samples.

Procedure. 34. The fixed cylinder shall be placed on a rigid support so that its sides are vertical. A lubricating oil with viscosity of 60 to 70 seconds Saybolt at 37.8° C. (100° F.) shall be placed in it to a depth of 12.7 cm. (5 in.). The specimen (one thickness only) shall be secured tightly under the clamp on the movable cylinder completely covering the aperture. The movable cylinder is then floated on the lubricating oil. The time required for the displacement of a certain amount of air is noted with a stop-watch. If possible, the amount of air displaced should be such that the time of displacement is not less than 20 seconds. The apparatus with its content of lubricating oil shall be at the temperature of the conditioning room when the readings are taken. The time in seconds required for the displacement of 100 cc. (6.1 cu. in.) through a circular area (one side only) of 6.44 sq. cm. (1 sq. in.) of the paper is known as the air resistance of the paper.

NOTE.—The clamp shall be tested for leakage by substituting a piece of tin foil 0.05 mm. (0.002 in.) in thickness for the paper and testing in the manner described above. When so tested, the leakage shall not exceed the rate of 50 cc. in five hours.

The proper procedure for clamping the specimen or tinfoil is to turn both knurled nuts down onto the clamp simultaneously. If only one nut at a time is turned down, the clamp will not fit flat on the specimen and will consequently have an avoidable leak.

Oil is used in preference to distilled water because it does not corrode aluminum whereas distilled water does.

Precautions should be taken to avoid subjecting the apparatus to vibration as this condition would increase the rate of air displacement.

Report. 35. The report shall include (1) the number of seconds required for the displacement of 100 cc. (6.1 cu. in.) of air; (2) the area of paper through which the air was displaced; (3) the thickness of the paper as obtained under Section 11 and (4) the room temperature.

ASH

Apparatus. 36. A suitable crucible such as platinum, nickel or porcelain, a balance sensitive to 0.1 mg., and a desiccator are necessary for the test.

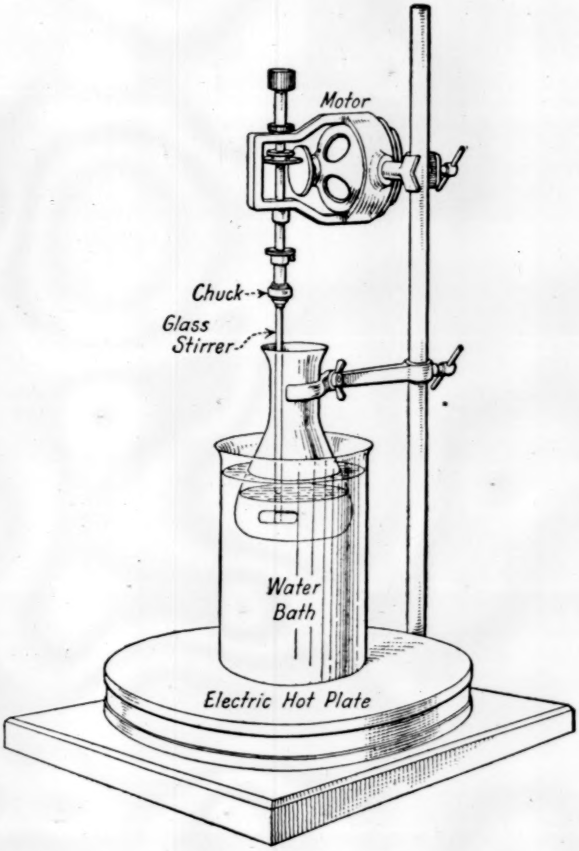

FIG. 2.—Extraction Apparatus.

Specimen. 37. Not less than 2 g. of dry, finely-divided paper from the "moisture determination" sample as obtained in accordance with Section 6 shall be used.

Procedure. 38. The sample shall be transferred rapidly from the weighing bottle containing the dried sample into the crucible. The weighing bottle shall immediately be re-stoppered and re-weighed, and the exact weight of the sample obtained by taking the difference in weights of the weighing bottle and the sample. The sample shall be completely ignited in the crucible, preferably in a muffle furnace, all precautions being taken to prevent loss of ash or sample. The residue of incombustible mineral matter (ash) shall be desiccated, cooled and weighed, and the amount computed as a percentage of the weight of the dried sample.

Report. 39. The amount of ash shall be reported as a percentage of the weight of the dry sample (see Section 7 (*a*)) and also as a percentage of the weight of the undried sample (see Section 7 (*b*)).

ACIDITY OR ALKALINITY

Apparatus. 40. (*a*) A hot water bath, electric hot plate, motor with stirrer, 50-cc. glass burette graduated to 0.1 cc., 250-cc. wide-mouth Erlenmeyer flasks, thermometer graduated to 1° C., covering the range from 50 to 100° C., and a filtering apparatus, are required for the test.

(*b*) The Erlenmeyer flasks and the stirrer shall be of acid- and alkali-resistant glass. The stirrer shall consist of a glass shaft, one end of which shall be fitted to a chuck attached to the motor shaft (see Fig. 2). The other end of the stirrer shall be fashioned into a two-bladed propeller, each blade to be approximately 15 mm. (0.59 in.) long and 6 mm. (0.24 in.) wide. The pitch of the blades and the direction of rotation shall be such as to produce a downward current along the glass shaft when the stirrer is rotated in the liquid, thus preventing spattering.

(*c*) The following reagents shall be required: Solutions of sodium hydroxide ($NaOH$) and sulfuric acid (H_2SO_4) in water, each being 0.01 *N* in strength; solution of 0.5 g. of phenolphthalein dissolved in 100 cc. of c. p. ethyl alcohol.

Sample. 41. (*a*) From the original samples obtained according to Section 2 (*a*), a composite sample of at least 5 g. (0.175 oz.) shall be cut into small pieces, approximately 1 cm. (0.4 in.) square. The sample shall be thoroughly mixed, and during preparation contamination by handling shall be avoided.

Procedure. 42. (*a*) *Extraction.*—One gram of the composite sample shall be placed in a 250-cc. Erlenmeyer flask and 100 cc. of boiling, distilled water added. The flask shall then be clamped in position in a water bath[1] heated to 100° C. on a hot plate. The level of the water in the bath shall be slightly above the level of that in the flask, and the temperature of the contents of the flask shall remain at least as high as 95° C. during the stirring operation. The stirrer shall be mounted so that the blades are within 3 mm. (0.12 in.) of the bottom of the flask and offset from the center in order to obtain best beating action. The stirrer shall be driven at a speed of 4000 to 5000 r.p.m. for 5 minutes. At the end of this period the sample should have been thoroughly pulped. For papers unusually difficult to pulp, the period of stirring shall be increased to 10 minutes.[1]

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[1] At high altitudes a salt bath will be necessary to obtain the temperature required.

NOTE.—It has been definitely determined that 3000 r.p.m. is too low to pulp the sample effectively within 5 minutes.

(*b*) *Titration.*—Immediately after the sample has been pulped, the contents of the flask shall be filtered rapidly into another 250-cc. Erlenmeyer flask without washing.

NOTE.—It is important that the filtration of the extract be accomplished as promptly as possible after disintegration to prevent re-absorption of acidic or alkaline material from the extract by the pulp as the temperature falls. A convenient method consists of a 25-cc. porcelain Gooch crucible and holder assembly, like that shown in Fig. 3. The pulp forms a filter mat of itself over the perforations in the bottom of the crucible and the first portion of the filtrate is re-filtered to catch the fibers which go through during the formation of the mat.

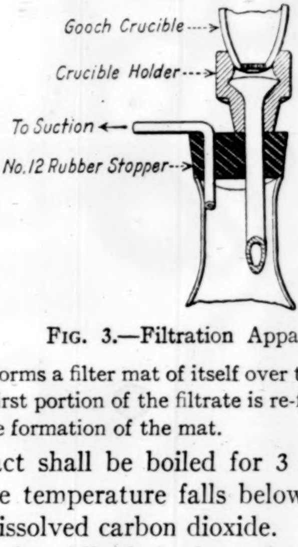

FIG. 3.—Filtration Apparatus.

The filtered extract shall be boiled for 3 minutes and immediately titrated before the temperature falls below 80° C., thus eliminating the error due to dissolved carbon dioxide.

If the extract is acidic, it is titrated with $0.01N$ NaOH, using 5 drops of the specified phenolphthalein solution as indicator. The end-point is determined by the appearance of a definite pink color. If the extract is alkaline, a small excess of $0.01N$ H_2SO_4 is added and the titration then completed with $0.01N$ NaOH as described above.

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[1] Any other method of pulping the sample as rapidly and thoroughly, while maintaining a tempera-true of 95° C. within the flask during extraction, should prove satisfactory.

NOTE.—To find the proper color transformation at the end-point, a blank titration should be made on boiling distilled water under the above specified conditions. The result should check with the curve shown in Fig. 4. This curve will be found valuable as a check on the purity of the distilled water used, although its chief purpose is to indicate the proper blank correction to be applied to the titration.

The number of cubic centimeters of titer solution shall be recorded, together with the temperature and volume of the solution taken immediately upon the completion of the titration, as these figures enter into the blank correction for the volume error (E_v).

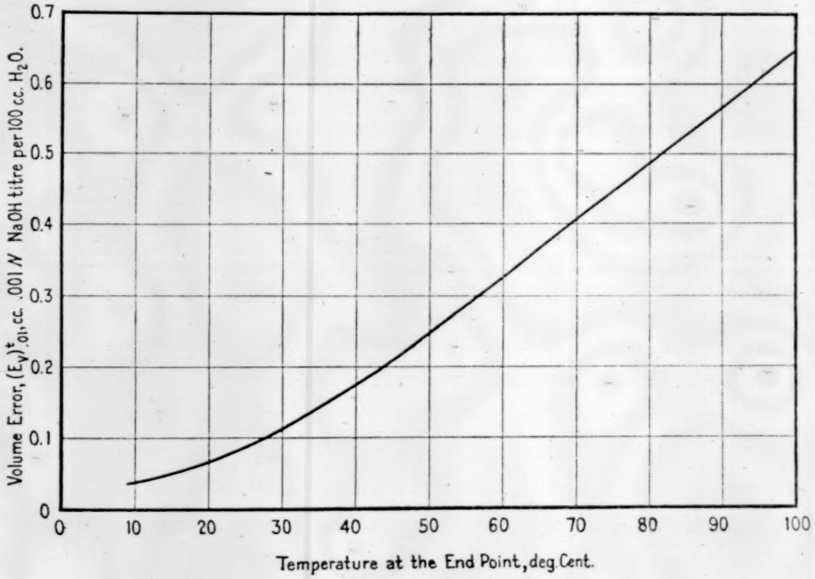

FIG. 4.—Showing Titration Error Due to Volume and Temperature of Water in a Solution at its End-Point.

If $(E_V)\frac{t}{N}$ represents the volume error of a solution where t and V are the temperature and volume at the end-point of a titration, and $N =$ the normality of the titer, then it is calculated as follows:

$$(E_V)\frac{t}{N} = (E_V)^t 0.01 \times \frac{0.01}{N} \times \frac{V}{100}$$

Report. 43. (*a*) *Blank Correction.*—The correction for the blank error in the titration shall be made in either of two ways:

(1) By running a blank in parallel with the actual determination using a volume of pure distilled water equal to that of the extract at the end-point;

(2) By calculating the blank error with the aid of the curve shown in Fig. 4.

NOTE.—The second method is the more convenient and probably more reliable. This curve shows the number of cubic centimeters of $0.01N$ NaOH solution required to produce an end-point at various temperatures in 100 cc. of distilled water, using 5 drops of the specified indicator. Correction by the use of this curve is valid only if the solution has been boiled and titrated at elevated temperatures to insure absence of dissolved CO_2.

This correction is the number of cubic centimeters of titer solution (volume error) corresponding to the point on the curve determined by the temperature and volume of the solution at the end-point. If the solution is acidic, this blank correction shall be subtracted from the volume of titer used; if alkaline the correction shall be added.

(*b*) *Calculation.*—The acidity or alkalinity shall be calculated from the following equation:

$$\text{Percentage acidity (or alkalinity)} = \left\{ \begin{matrix} \text{cubic centimeter titer} \\ \text{solution (corrected)} \end{matrix} \right\} \times \frac{\text{normality}}{1000} \times 40 \times 100$$

A simpler form is:

$$\text{Percentage acidity (or alkalinity)} = \left\{ \begin{matrix} \text{cubic centimeter} \\ \text{titer (corrected)} \end{matrix} \right\} \times \text{normality} \times 4.$$

(*c*) *Expression of Results.*—The results shall be expressed as the equivalent weight per cent of NaOH if the extract is acidic, or as equivalent weight per cent of SO_3 if the extract is alkaline; this percentage being based on the weight of the air-dry sample in grams.

NOTE.—SO_3 is used rather than H_2SO_4 in this calculation as the equivalent weight of SO_3 is identical with that of NaOH, and this makes it possible to express acidity or alkalinity in directly comparable terms.

(*d*) *Number of Tests.*—At least two samples shall be carried through the foregoing procedure. If in duplicate samples the values of percentage acidity or alkalinity do not agree within 0.005, the determinations shall be repeated.

NOTE.—There is given in an appendix to the report of Committee D-9 for 1926, information regarding the details of the foregoing method, and reasons are presented for the selection of the conditions specified.

SURVEY FOR CONDUCTING PATHS

Scope.

44. The survey for conducting paths in untreated insulating paper is a test to determine the number of conducting paths in the paper as indicated by the number of electrical breakdowns (or points of excessive current flow in thin papers (see Section 45 (*b*)) when relatively large areas of the paper are subjected to a voltage somewhat lower in value than the dielectric strength of the paper when tested in accordance with Sections 2 to 12 of the Tentative Methods of Testing Sheet and Tape Insulating Materials for Dielectric Strength

(Serial Designation: D 149 - 27 T) of the American Society for Testing Materials.[1]

Apparatus. 45. (*a*) The survey shall be made by passing a specimen of the paper between metallic electrodes across which a voltage is impressed. The arrangement of the apparatus may be of any convenient form which will allow the application of the required voltage to a specimen of relatively large area, and will allow the electrical breakdowns to be indicated so that the number of these may be counted.

(*b*) For papers having a thickness of 0.038 mm. (0.0015 in.) or less it has been found preferable to use a detecting device such as a telephone receiver to detect the excessive current through the conducting paths rather than to allow complete electrical breakdown of the specimen. Also, it is preferable to pass one electrode over the paper rather than to draw the paper through between the electrodes.

Specimens. 46. The specimen shall be of relatively large area, such as a pad of tape, or a sheet from each sample of paper (see Section 2 (*a*)). For sheet material such as pressboard either the entire sheet or a relatively large portion of a sheet shall be used. The specimen shall be representative of the shipment. (Section 2 (*a*)).

Procedure. 47. The survey shall be made by passing the specimen between the metallic electrodes at a speed of 30 to 60 ft. per minute. The voltage impressed across the electrodes shall be 100 volts per mil thickness of the specimen if alternating voltage is used, or 141 volts per mil thickness of the specimen if direct voltage is used.

NOTE 1.—If the voltage values specified above prove inconvenient of application, a lower voltage may be used, in which case it is necessary to establish a relationship between the conducting paths at this voltage and at the specified voltage. A lower value of conducting paths will be obtained at the lower voltage.

NOTE 2.—A description of equipment and a procedure which have been found suitable for making this survey of conducting paths in different thicknesses of paper may be had upon application to the secretary of Committee D-9.

Report. 48. The report shall include the following:

(*a*) The total number of conducting paths and the conducting paths per unit area.

(*b*) The length, width, area, and thickness of the specimen.

(*c*) The voltage applied expressed in volts, and volts per mil thickness of specimen.

(*d*) The speed of the paper.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 995 (1927); also 1928 Book of A.S.T.M. Tentative Standards, p. 617.

TENTATIVE METHODS OF TESTING LAMINATED SHEET INSULATING MATERIALS[1]

Serial Designation: D 229 - 28 T

This is a **Tentative Standard**, published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1925; REVISED, 1926, 1928.

Scope. 1. These tests apply to laminated flat sheet materials intended for use as electrical insulation.[2]

Definition of Terms. 2. In referring to the cutting of the specimens and the application of the load, the following definitions apply:

Flatwise.—Load applied to the face of the laminations.

Edgewise.—Load applied to the edge of the laminations.

Lengthwise.—In the direction of the length of the sheet.

Crosswise.—In the direction at right angles to the length of the sheet.

NOTE.—When the sheet has the same length and width, one dimension shall arbitrarily be designated as the length, and the other as the width.

TENSILE STRENGTH

Apparatus. 3. Any standard type of testing machine may be used. The machine shall be accurate to within 1 per cent on the lowest load for which it is used. Jaws which tighten under load, such as wedge grip jaws, shall be used with the specimen properly aligned.

Specimens. 4. Tension test specimens shall conform to the dimensions shown in Fig. 1. The surfaces of the specimen shall be smooth and free from scratches.

Procedure. 5. Five specimens cut lengthwise and five specimens cut crosswise of the sheet shall be tested.

Temperature. 6. All tests shall be made at normal room temperature of about 20° C. (68° F.).

Speed of Testing Machine. 7. The cross-head speed of the testing machine shall be such that the load can be accurately weighed, but shall not exceed 0.05 in. per minute when the machine is running idle.

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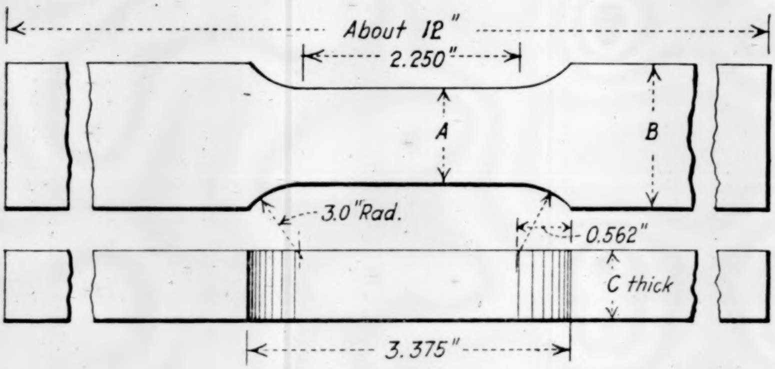
[1] Criticisms of these Tentative Methods are solicited and should be directed to Mr. T. S. Taylor, Secretary of Committee D-9 on Electrical Insulating Materials, Bakelite Corporation, 230 Grove St., Bloomfield, N. J.

[2] Tests for shearing strength, compressive strength, moisture absorption, oil absorption and degree of curing are being studied by the committee. Various mechanical tests, particularly applicable to thin laminated sheet materials, are being developed.

Modulus of Elasticity. 8. When it is desired to obtain the modulus of elasticity, a suitable extensometer measuring the elongation on a 2-in. gage length shall be used. The cross-head speed of the testing machine shall not exceed 0.03 in. per minute when the machine is running idle.

Procedure. 9. Strain readings shall be taken by increments of load not exceeding about 1000 lb. per sq. in. The modulus shall be calculated from the total change of length between zero load and stress of 5000 lb. per sq. in.

NOTE.—For some materials the stress strain curve will not forma straight line, but will be a continuous curve from the origin to the breaking load.



When C is less than $\frac{1}{8}$ in., A is $\frac{1}{2}$ in., B is $\frac{3}{4}$ in.
When C is over $\frac{1}{8}$ in., or over, A is 1 in., B is $1\frac{1}{2}$ in.

FIG. 1.—Tension Test Specimen for Laminated Sheet Insulating Materials.

Report. 10. The report shall include the following:

- (*a*) The direction in which the specimen was taken, whether lengthwise or crosswise of the sheet.
- (*b*) The thickness and width of each specimen in inches or centimeters.
- (*c*) The breaking load of each specimen, in pounds or kilograms.
- (*d*) The tensile strength of each specimen, in pounds per square inch or in kilograms per square centimeter.
- (*e*) The location and nature of the fracture.
- (*f*) The modulus of elasticity, if determined.
- (*g*) The room temperature.

FLEXURAL STRENGTH

(A) *For Materials $\frac{1}{8}$ in. Thick or Over*[1]

Apparatus. 11. (*a*) Any standard type of testing machine may be used. The machine shall have an accuracy of at least 1 per cent of the lowest load for which it is used.

(*b*) The specimen shall be tested as a simple beam loaded at the center. The supports shall have contact edges rounded to a radius of $\frac{1}{8}$ in. The load shall be applied midway between the supports by a pressure piece, the bearing edge of which shall be rounded to a radius of $\frac{1}{8}$ in. The distance between the points of support shall be 4 in. for edgewise tests of all thicknesses and eight times the nominal thickness of the material to be tested for tests in the flatwise direction.

Specimen. 12. The test specimen shall be $\frac{1}{2}$ in. in width except for specimens over $\frac{1}{2}$ in. in thickness tested in the flatwise direction, which shall have the width equal to the thickness of the specimen. The thickness shall be the full thickness of the sheet. The length shall be 1 in. greater than the distance between the points of support as specified in Section 11 (*b*).

Procedure. 13. The specimens shall be tested as follows:

(*a*) Five specimens cut lengthwise of sheet, tested flatwise.
(*b*) Five specimens cut lengthwise of sheet, tested edgewise.
(*c*) Five specimens cut crosswise of sheet, tested flatwise.
(*d*) Five specimens cut crosswise of sheet, tested edgewise.

Temperature of Tests. 14. All tests shall be made at normal room temperature of about 20° C. (68° F.).

Speed of Testing Machine. 15. The cross-head speed of the testing machine shall be such that the beam of the machine can be kept balanced, but shall not exceed 0.05 in. per minute when the machine is running idle.

Report. 16. The report shall include the following:

(*a*) The directions of cutting and loading of the specimen as specified in Section 13.

(*b*) The thickness and width of each specimen in inches or millimeters.

(*c*) The breaking load of each specimen in pounds or kilograms.

(*d*) The maximum fiber stress in pounds per square inch or kilograms per square centimeter calculated from the formula:

$$S = \frac{3\ Pl}{2\ bd^2}$$

where S = maximum fiber stress;

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[1] Conventional flexure tests in a flatwise direction are not recommended for materials thinner than $\frac{1}{8}$ in. nor in the edgewise direction for materials thinner than $\frac{1}{4}$ in.

P = breaking load in pounds or kilograms;
l = distance between supports in inches or centimeters;
b = width of specimen in inches or centimeters;
d = depth of specimen in inches or centimeters.

(*e*) The room temperature.

(*f*) The deflection at the center in inches or millimeters at a beam load corresponding to a calculated maximum fiber stress of 10,000 lb. per sq. in. (705 kg. per sq. cm.), if determined.

COMPRESSIVE STRENGTH

Apparatus. 17. Any standard testing machine may be used provided it is accurate within 1 per cent of the lowest load for which it is used. One end of the specimen shall bear upon an accurately centered spherical bearing block, located whenever practicable, at the top, and the metal bearing plates shall be directly in contact with the ends of the test specimen. The pressure heads used for standard compression tests of cement as described in the Tentative Specifications and Tests for Compressive Strength of Portland-Cement Mortars (Serial Designation: C 9 - 16 T) of the American Society for Testing Materials[1] are satisfactory for this test.

Specimen. 18. The test specimen shall be a 1-in. cube. The faces shall be flat and perpendicular to the axes, being ground to this condition if necessary.

Procedure. 19. Three specimens shall be crushed in the condition in which they are received with the load applied flatwise, three specimens with the load applied edgewise-lengthwise of the sheet and three specimens with the load applied edgewise-crosswise of the sheet.

20. The load shall be applied on the ends of the specimen and the crosshead speed of the testing machine shall be such that the load can be accurately weighed but shall not exceed 0.050 in. (1.27 mm.) per minute when the machine is running idle. For the best results use the slowest possible speed.

Report. 21. The report shall include the following:

(*a*) The dimensions of each specimen in inches or millimeters;

(*b*) The direction of application of the load;

(*c*) The load on each specimen in pounds or kilograms at the first sign of failure;

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. XX, Part I, p. 599 (1920); also 1928 Book of A.S.T.M. Tentative Standards, p. 206.

(*d*) The ultimate compressive strength in pounds per square inch or kilograms per square millimeter, of each specimen, calculated from the area of each specimen measured before the load is applied;

(*e*) The general character of the material tested; with a description of how it acts under the applied load.

WATER ABSORPTION TESTS

Scope. 22. The water absorption tests are intended to determine the rate at which water is absorbed by the material when immersed, the total quantity absorbed at saturation, and the volatile content as received.

NOTE.—The electrical properties of different materials are not necessarily affected to the same extent by the same increase in moisture content so that the water absorption test must be correlated with the desired electrical tests.

The water immersion test and exposure to air of high humidity are not always directly comparable and should be considered before substituting one for the other.

(*A*) *Rate of Absorption*

Specimen. 23. The test specimen shall be 3 by 1 in. by the thickness of the material. It shall be sawed or sheared from the sample so as to have smooth edges free from cracks. The cut edges of all test specimens shall be finished with No. 0 or finer sandpaper or emery cloth. Sawing and sandpapering operations should be slow enough so that the material is not heated appreciably. The thickness in inches to the nearest 0.001 in. shall be measured on the original specimen at the center.

Procedure. 24. To determine the rate of absorption, two specimens shall be tested individually as follows:

(*a*) The specimen shall be weighed, dried in an oven for 1 hour at from 105 to 110° C., cooled in a desiccator and immediately re-weighed. The difference between the original weight and the dry weight shall be recorded as loss in weight on drying. The percentage loss in weight shall be calculated on the original weight.

(*b*) The dried specimen shall then be immersed in distilled water at a temperature of from 20 to 30° C. At the end of 2 hours the specimen shall be removed from the water, the surface water wiped off with a dry cloth and the specimen weighed immediately and then replaced in the water. If the specimen is $\frac{1}{16}$ in. in thickness or less it shall be weighed in a weighing bottle. The difference between the weight of the wet specimen and that of the dry specimen shall be recorded as the weight of water absorbed in 2 hours. The percentage of water absorbed shall be calculated on the weight of the dry specimen.

(*c*) After 24 hours immersion the specimen shall again be removed from the water, the surface water wiped off with a dry cloth and the specimen weighed. The difference between the weight of the specimen after 24 hours immersion and the weight of the dry specimen shall be recorded as the water absorbed in 24 hours. The percentage of water absorbed shall be calculated on the weight of the dry specimen. If the individual 24-hour absorptions differ by more than 10 per cent from the average absorption of the two specimens the test shall be repeated.

Report. 25. The report shall include the values for each of the two specimens and the average values as follows:

(*a*) The thickness of the specimen before the test, to the nearest 0.001 in.;

(*b*) The percentage loss in weight on drying calculated on the original weight;

(*c*) The percentage of water absorbed in 2 hours and in 24 hours calculated on the dry weight.

(*B*) *Total Absorption at Saturation*

Specimen. 26. (*a*) The test specimen shall be 3 by 1 in. by the thickness of the material. It shall be sawed or sheared from the sample so as to have smooth edges free from cracks. The cut edges of all test specimens shall be finished with No. 0 or finer sandpaper or emery cloth. Sawing and sandpapering operations should be slow enough so that the material is not heated appreciably. The thickness in inches measured to the nearest 0.001 in. shall be measured on the original specimen at the center and on the reduced specimen in case a reduced specimen is used (see Paragraph (*b*)).

(*b*) When the sample for determining total absorption is so thick that too long a time is required for saturation using the full thickness, the thickness may be reduced as follows: The sample shall be machined to a thickness of about $\frac{5}{64}$-in., both surfaces parallel to the laminations being machined off. This may readily be done with a smooth-cut circular saw. It shall then be sanded to $\frac{1}{16}$ in. in thickness, finishing with No. 0 or finer sandpaper. While the sanded surfaces of the sample should be approximately parallel with the laminations, the thickness may vary ±0.010 in., since the object is to provide comparable specimens which will reach saturation in a reasonable time. The machined and sanded sample shall then be cut into specimens 3 by 1 in. and the edges sanded.

27. To determine the total water absorption at saturation, two specimens shall be tested individually as follows: **Procedure.**

(*a*) The specimen shall be weighed, dried in an oven for 1 hour at from 105 to 110° C., cooled in a desiccator and immediately reweighed. The difference between the original weight and the dry weight shall be recorded as loss of weight on drying. The percentage loss in weight shall be calculated on the original weight.

(*b*) The dried specimen shall then be immersed in distilled water at a temperature of from 20 to 30° C. At the end of 24 hours the specimen shall be removed from the water, the surface water wiped off with a dry cloth and the specimen weighed immediately and then replaced in the water. The weighings shall be repeated every day for the first week and every week thereafter until the increase in weight, as shown by three consecutive weighings, averages less than 1 per cent of the total increase in weight, when the specimen shall be considered to be saturated.

(*c*) The difference between the saturated weight and that of the dry weight shall be considered as the water absorbed at saturation. The percentage of water absorbed shall be calculated on the dry weight of the specimen.

28. This report shall include the values for each of the two specimens as follows: **Report.**

(*a*) The original thickness of material, measured to the nearest 0.001 in.;

(*b*) If a reduced specimen is used, the thickness measured to the nearest 0.001 in.;

(*c*) The percentage loss in weight on drying, calculated on the original weight;

(*d*) The percentage of water absorbed at saturation, calculated on the dry weight.

(*C*) *Volatile Matter*

29. The test specimen shall conform to the requirements specified in Section 12. **Specimen.**

30. To determine the volatile matter, two specimens shall be tested individually as follows: **Procedure.**

The specimen shall be weighed, dried in an oven at from 105 to 110° C. until the decrease in weight as shown by two consecutive weighings at least 24 hours apart is less than 1 per cent of the total decrease in weight. The difference between the original weight and the dry weight shall be recorded as the volatile matter present in the specimen as received (this includes in addition to water any volatile solvent left during manufacture). The percentage of volatile matter shall be based on the weight of the dry specimen.

Report.

31. The report shall include the values for each of the two specimens as follows:

(*a*) The original thickness of the material measured to the nearest 0.001 in.;

(*b*) The percentage of volatile matter, based on the weight of the dry specimen.

DIELECTRIC STRENGTH

Dielectric Strength.

32. The dielectric strength shall be determined in accordance with the Tentative Methods of Testing Sheet and Tape Insulating Materials for Dielectric Strength (Serial Designation: D 149 - 27 T) of the American Society for Testing Materials.[1]

PHASE DIFFERENCE (POWER FACTOR) AND DIELECTRIC CONSTANT

Dielectric Constant.

33. The phase difference and dielectric constant shall be determined in accordance with the Tentative Methods of Testing Electrical Insulating Materials for Power Factor and Dielectric Constant at Frequencies of 100 to 1500 Kilocycles (Serial Designation: D 150 - 27 T) of the American Society for Testing Materials.[2]

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 995 (1927); also 1928 Book of A.S.T.M. Tentative Standards, p. 617.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 1003 (1927); also 1928 Book of A.S.T.M. Tentative Standards, p. 625.

TENTATIVE METHODS OF TESTING INSULATING MATERIALS FOR RESISTANCE TO IMPACT[1]

Serial Designation: D 256 - 28 T

This is a Tentative Standard, published for the purpose of eliciting criticism and **suggestions, and as such is subject to annual revision.**

Issued, 1926; Revised, 1928.

Scope.

1. (*a*) These methods are intended to determine the relative toughness of electrical insulating materials as indicated by the energy used in breaking a standard test specimen in one blow.

(*b*) This type of impact test is made by machines of the pendulum type of which there are two kinds, the Charpy and the Izod, which differ only in the method of holding and striking the specimen. In the Charpy test the specimen is held as a simple beam (usually horizontal) and is broken by a blow delivered midway between the supports. In the Izod test the specimen is held as a cantilever beam (usually vertical) and is broken by a blow delivered at a fixed distance from the edge of the specimen clamp. The Charpy test may be made on either a plain or a notched specimen as required by the characteristics of the material tested. The Izod test requires a notched specimen in all cases.

Note.—For general information on impact testing see Appendices III and IV to the 1926 Report of Committee E-1 on Methods of Testing, *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, pp. 546, 553 (1926).

APPARATUS

A. Simple Beam Method (Charpy Test).

Simple Beam. Machine.

2. (*a*) The machine used in the simple beam method shall be of the pendulum type as shown in Fig. 1, of rigid construction and accurate to within 0.01 ft.-lb. for values of impact strength less than 1 ft-lb. and to within 1 per cent for higher values of impact strength. Accurate correction shall be made for friction and windage losses.

(*b*) The dimensions of the machine shall be such that the center of percussion of the striker (Note) is at the point of impact, that is, the center of the striking edge.

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[1] **Criticisms of these Tentative Methods are solicited and should be directed to Mr. T. S. Taylor, Secretary of Committee D-9 on Electrical Insulating Materials, Bakelite Corporation, 230 Grove St., Bloomfield, N. J.**

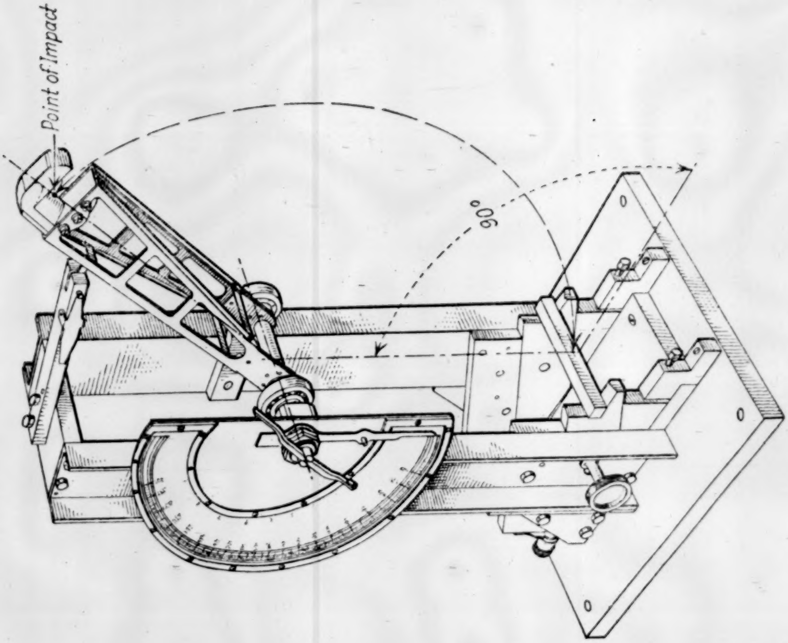
Point of Impact
90°

FIG. 1.—Simple Beam (Charpy) Impact Machine.

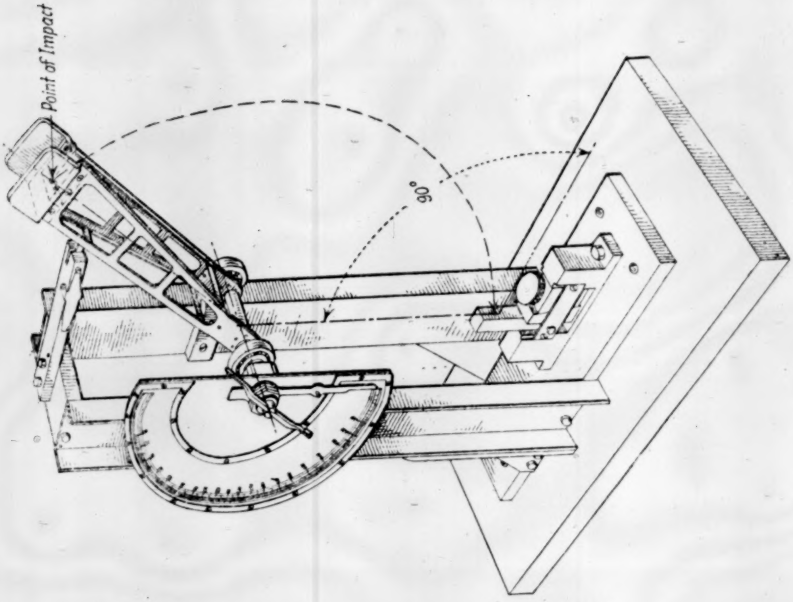
Point of Impact
90°

FIG. 2.—Cantilever Beam (Izod) Impact Machine.

NOTE.—The distance from the axis of support to the center of percussion, l, may be determined experimentally from the period of oscillation of the pendulum through a small angle by means of the expression $l = 0.81\ P^2$, where P is the time in seconds of a complete swing (to and fro).

(*c*) The pendulum shall be released from such a position that the linear velocity of the center of the striking edge (center of percussion) at the instant of impact shall be approximately 11 ft. per second, which is that corresponding to an initial elevation of this point of 2 ft.

(*d*) The striking edge of the pendulum shall be tapered to have an included angle of 45 deg. and shall be rounded to a radius of 0.125 in. (3.175 mm.). It shall be so aligned that in the case of rectangular specimens it will make contact across the full width of the specimen.

(*e*) The test specimen shall be supported against two rigid blocks in such a position that its center of gravity shall lie on a tangent to the arc of travel of the center of percussion of the pendulum drawn at the position of impact. The edges of the blocks shall be rounded to a radius of 0.125 in. (3.175 mm.) and the points of support shall be 4 in. (10.16 cm.) apart.

(*f*) Means shall be provided for determining the impact strength. The impact strength shall be taken as the energy absorbed in breaking the specimen, and is equal to the difference between the energy in the pendulum blow and the energy remaining in the pendulum after breaking the specimen.

B. Cantilever Beam Method (Izod Test).

Cantilever Beam Machine.

3. (*a*) The machine used for the cantilever-beam method shall be of the pendulum type as shown in Fig. 2, of rigid construction and accurate to within 0.01 ft-lb. for values of impact strength less than 1 ft-lb. and to within 1 per cent for higher values of impact strength. Accurate correction shall be made for friction and windage losses.

(*b*) The dimensions of the machine shall be such that the center of percussion of the striker is at the striking edge.

(*c*) The pendulum shall be released from such a position that the linear velocity of the striking edge at the instant of impact shall be approximately 11 ft. per second, which is that corresponding to an initial elevation of the striking edge of 2 ft.

(*d*) The striking edge of the pendulum shall be an unrounded edge formed, in the position of impact, by the intersection of a plane inclined away from the specimen at an angle of 5 deg. from the vertical with another plane perpendicular to the specimen, and shall be so aligned as to make contact across the full width of the specimen. In the striking position the striking edge shall be 0.866 in. from the edge of the specimen clamp.

(*e*) Means shall be provided for clamping the specimen rigidly in position with the edges of the supporting surfaces at 90-deg. angles.

(*f*) Means shall be provided for determining the impact strength. The impact strength shall be taken as the energy absorbed in breaking the specimen, and is equal to the difference between the energy in the pendulum blow and the energy remaining in the pendulum after breaking the specimen.

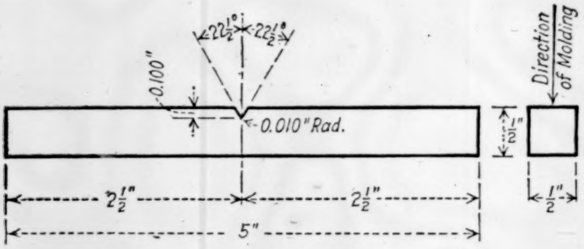

FIG. 3.—Simple Beam (Charpy) Impact Test Specimen.

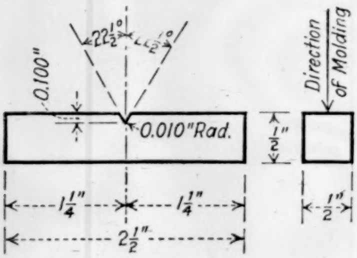

FIG. 4.—Cantilever Beam (Izod) Impact Test Specimen

TEST SPECIMEN

A. *Simple Beam Method* (Charpy Test).

Charpy Test Specimen.

4. (*a*) For insulating materials other than ceramic materials the specimen shall conform to the dimensions shown in Fig. 3. The notch may be milled, filed, or molded provided the bottom of the resulting notch is smooth, straight and free from scratches.

(*b*) For ceramic materials the specimen shall be an unnotched cylinder 6 in. (15.2 cm.) in length. The diameter shall be 0.5 in. (1.27 cm.), 0.75 in. (1.91 cm.), or 1.125 in. (2.86 cm.), whichever value is comparable to that of the finished product.

B. *Cantilever-Beam Method* (Izod Test).

Izod Test Specimen.

5. For insulating materials not including ceramic materials the specimen shall conform to the dimensions shown in Fig. 4. The notch

may be milled, filed or molded provided the bottom of the notch is smooth, straight and free from scratches. Sheet materials shall be tested edgewise or flatwise as specified (Note).

NOTE.—In referring to the cutting of the specimens of laminated sheet materials and the application of the load, the following definitions apply:

Flatwise.—Load applied to the face of the laminations.

Edgewise.—Load applied to the edge of the laminations.

METHOD

A. *Simple Beam Method* (Charpy Test).

Charpy Procedure.

6. (*a*) Five specimens shall be broken for each test.

(*b*) The specimen shall be supported against the steel blocks so that the blow will be struck at the center of the specimen and on the side opposite the notch for notched specimens.

B. *Cantilever Beam Method* (Izod Test).

Izod Procedure.

7. (*a*) Five specimens shall be broken for each test.

(*b*) The specimen shall be rigidly clamped with the center line of the notch on the level of the top of the clamping surfaces (Note) and the blow shall be struck on the notched side.

NOTE.—It is recommended that a template be used to locate the specimen in the jaws as specified.

REPORT

Report.

9. The report of the test shall include the following:

(*a*) A statement indicating the type of test, the specimen used and for sheet materials the direction of testing.

(*b*) The value of the energy absorbed in breaking each specimen, expressed in foot-pounds.

(*c*) The average of the values given in Paragraph (*b*).

TENTATIVE METHODS OF TESTING VARNISHED CLOTH TAPES[1]

Serial Designation: D 295 - 28 T

This is a Tentative Standard, published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1928.

Scope. 1. These methods are intended to apply to varnished cloth tapes which are to be used as electrical insulation and are directly applicable to both the "straight-cut" and "bias-cut" tapes, unless otherwise stated in the method.

SAMPLING

Sampling. 2. (*a*) From shipments consisting of rolls (or pads), at least one roll shall be selected from each 100 rolls in the shipment, but in no case shall less than two rolls be taken from a shipment and the rolls shall be selected in such a manner as to be representative of the shipment.

(*b*) The number of specimens required for purposes of test shall be cut from the rolls selected in Paragraph (*a*), and the length of the specimens shall be not less than 91.44 cm. (36 in.) for straight tapes; from seam to seam for sewed bias-cut tapes; and from jointed-selvage to jointed-selvage for seamless bias-cut tapes.

NOTE 1.—Specimens of bias tapes cut in the above manner will exclude seams and jointed-selvages from the test areas.

NOTE 2.—If it is desired to test the seams or jointed-selvages for tensile breaking strength, additional specimens will have to be cut so that the seams or jointed-selvages are in the center of the specimens.

(*c*) Not less than 6 turns of tape from each sample roll taken shall be torn off and discarded before the specimens are selected.

3. From shipments such as strips of tape, the number of samples required for purposes of test shall be taken in such a manner as to be equally representative of the shipment.

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[1] Criticisms of these Tentative Methods are solicited and should be directed to Mr. T. S. Taylor, Secretary of Committee D-9 on Electrical Insulating Materials, Bakelite Corporation, 230 Grove St., Bloomfield, N. J.

CONDITIONING

4. Specimens shall be conditioned for at least 2 hours in air maintained at a temperature between the limits of 20 and 30° C. (68 and 86° C.), before testing. **Conditioning.**

THICKNESS

5. (*a*) A micrometer of the spring actuated, dial type, conforming to the requirements specified in Section 8 of the Tentative Methods of Testing Untreated Insulating Paper (Serial Designation: D 202-28 T) of the American Society for Testing Materials[1] shall be used for determining the thickness of the tape. **Apparatus.**

6. (*a*) In making thickness measurements, only one layer of tape shall be used and the micrometer plunger shall be raised to a point where its lower surface is from 0.45 to 0.55 mm. (0.018 to 0.021 in.) above the surface of the tape specimen lying in contact with the surface of the fixed anvil. The plunger shall be dropped from this point on to the tape without retarding its speed of descent. When the thickness is read, care shall be taken not to touch the instrument. **Procedure.**

NOTE.—When the tape is wider than the diameter of the plunger face of the micrometer, care shall be taken to ascertain that measurements are made staggered across the width of the tape.

(*b*) Not more than five readings shall be taken equally spaced along each specimen length and the thickness of the tape shall be the average of ten measurements taken on at least two specimen lengths.

7. The report shall include the average, maximum and minimum thicknesses. **Report.**

TENSILE BREAKING STRENGTH

8. (*a*) A testing machine of the dead-weight pendulum type used for the testing of paper as specified in Section 12 of the Tentative Methods of Testing Untreated Insulating Paper (Serial Designation: D 202 - 28 T)[1] shall be used for this test. The machine shall preferably be power driven. **Apparatus.**

(*b*) The capacity of the machine shall not exceed 113 kg. (250 lb.).

(*c*) The machine shall be graduated to read 1 lb. or 1 kg. or less per scale division for testing tape breaking at 22.7 kg. (50 lb.) or over, and to 0.5 lb. or 0.5 kg. or less for testing tape breaking under 22.7 kg. (50 lb.).

9. Ten specimens selected in accordance with Section 2 or 3 shall be subjected to the tensile breaking strength test. The tensile breaking strength of the tape shall be the average of the ten tests. **Specimens.**

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[1] See p. 998.

Procedure. 10. (*a*) The ratio of the clearance distance between jaws to the width of the specimen shall be not less than 5 to 1 nor more than 10 to 1.

(*b*) The rate of travel of the movable jaw shall be constant. It shall preferably be 30.5 cm. (12 in.) per minute, but it may be within the limits of 28 cm. (11 in.) and 33 cm. (13 in.) per minute provided it is constant.

(*c*) All readings obtained when the tape breaks at or in the jaws shall be rejected.

Report. 11. The report shall include the average, maximum and minimum breaking loads of the ten specimens in kilograms or pounds together with the width of the specimen and the average thickness in millimeters or inches.

NOTE.—If it is desired to test the seams or jointed-selvages for tensile breaking strength, specimens as obtained in Note 2 under Section 2 (*b*) shall be clamped in the testing machine so that the seams or jointed-selvages are midway between the two jaws. When testing, all readings obtained when the tape breaks away from the seam or jointed-selvage shall be rejected.

DIELECTRIC STRENGTH

Dielectric Strength. 12. The dielectric strength of the tape shall be determined in accordance with the Tentative Methods of Testing Sheet and Tape Insulating Materials for Dielectric Strength (Serial Designation: D 149 - 27 T) of the American Society for Testing Materials.[1]

ELONGATION, DEFORMATION, AND CRITICAL LOAD

(*In the Case of Bias-Cut Tapes*)

Scope. 13. (*a*) This method is intended to determine the effect of mechanical tension on bias-cut varnished cloth tapes.

(*b*) When a bias-cut tape is weighted with a load, the length to which it will be stretched increases with time until it reaches a maximum value. The difference between this length and the original length is called the "elongation." For average tapes, the time to reach maximum elongation is between 20 and 35 minutes.

(*c*) If the load is then removed from the tape, it decreases in length until it reaches a final elongation. The difference between this length and the original length is the amount of permanent elongation imparted to the tape and is called the "deformation." For average tapes, the time to reach final elongation (deformation) is between 5 and 20 minutes.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 995 (1927); also 1928 Book of A.S.T.M. Tentative Standards, p. 617.

NOTE.—It will be noted in Section 16, that the maximum time to reach elongation and deformation has been selected in each case, namely, 35 and 20 minutes, respectively.

(*d*) A characteristic feature of the test is that at increasing loads the dielectric strength remains almost constant until a critical load is attained, under which load the elongation and deformation are small. When the load is increased over the critical value, the tape is stretched considerably and the elongation and deformation are large and the dielectric strength drops rapidly to a fraction of the original dielectric strength before the critical load is reached. Therefore, the load at which the dielectric strength of the tape is considerably lowered is considered the "critical load."

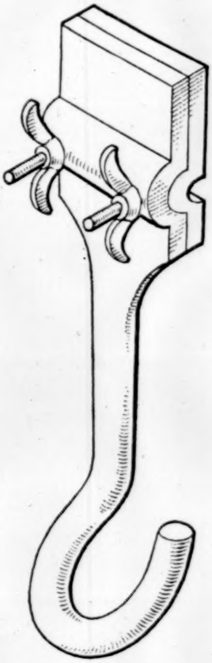

FIG. 1.—Clamp for Elongation and Deformation Test.

14. The apparatus required for the test shall consist of a pair of clamps for gripping the ends of the specimen. The clamps shall not be less than 5.08 cm. (2.0 in.) in width and one shall be provided with means for attaching to a fixed support and the other with means for affixing suspended weights. See Fig. 1 for suggested form of clamp. **Apparatus.**

15. (*a*) The test specimens for this test shall be selected in accordance with Section 2 (*b*). They shall not exceed 3.81 cm. (1.5 **Specimens.**

in.) in width. Tapes of greater width than this shall be cut to 3.81 cm. (1.5 in.) or less before testing.

(*b*) The total number of specimens required for this test will depend upon the number of trials that are required for the determination of the critical load. A set of three specimens shall be used for test at each load.

Procedure. 16. (*a*) *Elongation and Deformation.*—A set of three test specimens shall be tested individually at each specific load, as follows: A gage length, L, shall be marked on the test specimen and the specimen shall be fastened between the two clamps so that the test length is centrally located between the clamps. The gage length, L, shall be determined from the ratio:

$$\frac{L}{W} = 10$$

where W = the width of the specimen.

The clearance distance, D, between the jaws of the clamps shall be determined from the ratio:

$$\frac{D}{W} = 22$$

The test specimen shall be weighted with a load M (including the weight of the clamp) and at the end of 35 minutes the distance between gage lines, L_1, shall be determined and the load then removed. After the load is removed the tape decreases in length. At the end of 20 minutes the distance between the gage lines, L_2, shall be measured.

The percentage elongation and deformation shall be calculated from the following formulas:

$$\text{Percentage elongation} = \frac{L_1 - L}{L} \times 100;$$

$$\text{Percentage deformation} = \frac{L_2 - L}{L} \times 100$$

where L = the original gage length, in millimeters or inches;

L_1 = the distance between gage lines under load (maximum elongation), in millimeters or inches;

L_2 = the distance between gage lines after removal of the load (final elongation), in millimeters or inches.

The percentage elongation and deformation at each load shall be the average of the individual determinations made on the set of three specimens.

(*b*) *Dielectric Strength.*—Five dielectric strength tests shall be made on the gage lengths of the set of three specimens in accordance with method *A* for Short-Time Dielectric Strength Test as described in Sections 2 to 12 inclusive of the Tentative Methods of Testing Sheet and Tape Insulating Materials for Dielectric Strength (Serial Designation: D 149 - 27 T) of the American Society for Testing Materials.[1]

(*c*) *Thickness.*—The thickness shall be determined in accordance with Section 6 on the set of three specimens at each dielectric strength puncture, and the average of the five measurements shall be considered as the thickness.

Critical Load. 17. The determinations described in Section 16 shall be repeated on sets of three specimens at gradually increasing loads (for example, $M = 2, 4, 6, 8$, etc., lb. per inch of width) until the load reaches a value at which the dielectric strength is considerably less than the values previously determined. This value of the load shall be considered the critical load.

Graphical Record. 18. The results shall be represented graphically on the same sheet of graph paper by plotting as ordinates the average dielectric strength in volts per mil; the percentage elongation; and the percentage deformation against the load in kilograms or pounds as abscissa.

Report. 19. The significant values which shall be reported are as follows:

(*a*) The average dielectric strength in volts per mil at each load up to and including the critical load;

(*b*) the critical load in pounds or kilograms;

(*c*) the percentage elongation at each load, up to and including the critical load;

(*d*) the percentage deformation at each load, up to and including the critical load.

RESISTANCE TO OIL

Scope. 20. The test for resistance to oil is a comparative test only. It is intended to give an indication of the effect of oil on the varnish film of the varnished cloth tape. Results are determined by comparing a tested specimen with a specimen of the original tape.

Specimens and Procedure. 21. Three pieces, each 15.24 cm. (6.0 in.) in length, shall be cut from the specimens and immersed, for 48 hours in a specified oil, maintained at a temperature of 100° C. (212° F.) to within ±5° C. (9° F.). At the end of this time, the pieces shall be removed from the oil, allowed to cool to room temperature and wiped with a piece of dry cheesecloth.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 995 (1927); also 1928 Book of A.S.T.M. Tentative Standards, p. 617.

Examination. 22. The effect of oil on the varnish film is indicated by evidences of disintegration, which may be detected by the following:

(*a*) The examination of the used oil for "turbidity."

NOTE.—The oil may be considered "turbid" if a sample of used oil filtered through filter paper can be distinguished from an unfiltered sample of the used oil when the two samples, in identical containers, are held in front of a diffused light.

(*b*) The examination of the varnish film for apparent softening or excessive tackiness.

(*c*) The partial or complete removal of the film on wiping.

Report. 23. The tape shall be reported as passing the test when none of the strips show evidence of disintegration when examined in accordance with Section 22.

RESISTANCE TO PETROLATUM

Specimens and Procedure 24. Three pieces, each 15.24 cm. (6.0 in.) in length, shall be cut from the specimens and immersed, for 15 minutes, in melted No. 5 (or better quality) petrolatum, maintained at a temperature of 150° C. (302° F.) to within ± 5° C. (9° F.). At the end of this time, the pieces shall be removed from the petrolatum, wiped with a piece of dry cheesecloth and allowed to cool to room temperature.

Examination. 25. For the effect of petrolatum on the varnish film, the specimens shall be examined in accordance with Section 22 (*b*) and (*c*).

Report. 26. The results shall be reported as specified in Section 23.

WEIGHT

Weight. 27. Specimens of sufficient size to weigh not less than 5 g. (0.18 oz.) shall be accurately weighed on an analytical balance and the weight shall be reported on some commercial unit basis such as, the weight per square yard, the weight per gross yard per 1 in. in width, or the weight per roll.

THREADS PER INCH

Count. 28. The count or threads per inch of the varnished cloth tape shall be determined separately on the warp and filling by counting a space of not less than 1 in. (2.54 cm.) in at least five different places in the sample strip (or strips). The average of the five determinations shall be the count.

Report. 29. The results of the warp count and the filling count shall be reported separately as threads per inch.

NOTE 1.—The "warp" threads in straight tapes are the threads which are parallel with the length dimension, while in bias tapes the warp threads are parallel with the seams and jointed-selvages.

NOTE 2.—Before counting black varnished cloth tape it will be necessary to remove the varnish film with a knife blade or other suitable instrument. Liquid varnish removers are unsuitable for this purpose as they cause a swelling of the fibers and a shrinkage of cloth with a consequent increase in threads per inch; therefore, the films must be removed mechanically.

TENTATIVE SPECIFICATIONS
FOR
INSULATED WIRE AND CABLE: 30-PER-CENT HEVEA RUBBER[1]

Serial Designation: D 27 – 28 T

This is a Tentative Standard, published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1916; REVISED, 1921, 1928.

Scope. 1. These specifications cover conductors, rubber insulation, rubber-filled cloth tape and braid. The design and factor of safety depend upon the service conditions and shall be at the option of the purchaser.

(*A*) CONDUCTOR

MANUFACTURE

Material. 2. The conductor shall be of soft annealed copper, properly tinned, and have the properties and characteristics herein required.

Strand. 3. Each individual wire of a stranded conductor shall be considered separately and shall be designated as a strand.

Shape. 4. Each solid conductor and each strand shall be round and reasonably free from imperfections.

Stranding. 5. The stranding shall be concentric and unless otherwise specified shall conform to either Table I or Table II.

Density. 6. For the purpose of calculating weights, cross-sections, etc., in conductivity determinations, the density of copper shall be taken as 8.89 g. per cu. cm. (See Appendix.)

PERMISSIBLE VARIATIONS IN DIMENSIONS

Diameter and Area. 7. (*a*) *Permissible Variation.*—When the diameter of solid conductors and strands is specified, the permissible variation from the specified value shall not exceed 1 per cent under or 2 per cent over for wire 0.02 in. in diameter and larger, and 0.1 mil under for wire less than 0.02 in. in diameter.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. Arthur W. Carpenter, Secretary of Committee D-11 on Rubber Products, The B. F. Goodrich Co., Akron, Ohio.

TABLE I.—STRANDING OF CONCENTRIC-LAY CABLES.

(AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS STANDARD NO. 30)

Size of Conductor (See Note 1)		Number of Wires (See Note 2)	
Circular Mils or A.w.g. Numbers	sq. mm.	A Bare, Insulated or Weatherproof Cables for Aerial Use	B Insulated Cables for Other than Aerial Use
2 000 000 cir. mils	1013	91	127
1 500 000 cir. mils	760	61	91
1 000 000 cir. mils	507	61	61
600 000 cir. mils	304	37	61
500 000 cir. mils	253	37	37
400 000 cir. mils	203	19	37
No. 0000 A.w.g	107	19 or 7 (See Note 3)	19
No. 00 A.w.g	67.4	7	19
No. 2 A.w.g.	33.6	7	7
No. 7 A.w.g. and smaller	10.5	..	7

NOTE 1.—For intermediate sizes, use stranding for next larger size.

NOTE 2.—Conductors of No. 0000 A.w.g. and smaller are often made solid and this table of stranding should not be interpreted as excluding this practice.

NOTE 3.—Class A cables, sizes Nos. 0000 and 000 A.w.g., are usually made of 7 strands when bare and 19 strands when insulated or weatherproof.

TABLE II.—STRANDING OF FLEXIBLE CABLES.

(AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS STANDARD NO. 30)

Size of Conductor		Diameter of Cable, mils	Number of Wires	Size of Each Wire		Construction[c]
Nearest[a] A.w.g. Number	Circular mils[b]			A.w.g.	Diameter, mils	
	2 039 000	1885	703	15.5	53.9	37 by 19
	1 816 000	1779	703	16.0	50.8	37 by 19
	1 617 000	1679	703	16.5	48.0	37 by 19
	1 440 000	1584	703	17.0	45.3	37 by 19
	1 284 000	1496	703	17.5	42.7	37 by 19
	1 103 000	1372	427	16.0	50.8	61 by 7
	874 600	1222	427	17.0	45.3	61 by 7
	693 600	1088	427	18.0	40.3	61 by 7
	550 000	969	427	19.0	35.9	61 by 7
	436 200	863	427	20.0	32.0	61 by 7
	345 900	768	427	21.0	28.5	61 by 7
	274 300	684	427	22.0	25.3	61 by 7
	264 600	671	259	20.0	32.0	37 by 7
0000	209 800	598	259	21.0	28.5	37 by 7
000	171 300	538	133	19.0	35.9	19 by 7
00	135 900	479	133	20.0	32.0	19 by 7
0	107 700	427	133	21.0	28.5	19 by 7
1	82 780	332	91	20.5	30.2	Concentric
2	65 650	295	91	21.5	26.9	Concentric
3	52 060	263	91	22.5	23.9	Concentric
4	39 190	228	61	22.0	25.3	Concentric
5	31 080	203	61	23.0	22.6	Concentric
6	24 650	181	61	24.0	20.1	Concentric
8	17 410	152	61	25.5	16.9	Concentric
10	10 560	118	37	25.5	16.9	Concentric
12	6 640	94	37	27.5	13.4	Concentric
14	4 176	74	37	29.5	10.6	Concentric
Smaller than No. 14	....	....	[d]	30.0	....	Bunched

[a] The A.w.g. cross-sectional areas except for 61-strand cable are approximated within 2 per cent. In the case of 61-strand cables the approximation is 6 per cent.

[b] Circular mils are based on theoretical diameters of A.w.g. sizes, which vary above or below values given in the table by less than 0.1 mil.

[c] A construction of "61 by 7" in the rating of a rope-lay cable signifies 61 strands of 7 wires each.

[d] As required to equal the size specified.

NOTE.—These limits differ from those in the Standard Specifications for Tinned Soft or Annealed Copper Wire for Rubber Insulation (Serial Designation: B 33) of the American Society for Testing Materials[1] because of the additional manipulation to which the wire is subjected subsequent to the stage where Specifications B 33 apply.

When the area of cross-section of cables is specified, the permissible variation shall not exceed 1 per cent under the specified value.

(*b*) *Method of Gaging Diameter.*—When wire is submitted in coils, each coil shall be gaged in three places, one near each end and one approximately at the middle. When wire is submitted on spools or reels, approximately 12 ft. of the wire shall be reeled off and the wire then gaged in six places between the second foot and the twelfth foot from the end.

(*c*) *Calculation of Area.*—The area of cross-section of wire shall be calculated from the average of the measurements of the diameter made in accordance with Paragraph (*b*). The area of cross-section of cable shall be considered to be the sum of the cross-sectional areas of its component wires, when laid out straight and measured perpendicular to their axes.

TABLE III.—TENSILE REQUIREMENTS OF CONDUCTORS.

Size of Conductor		Maximum Tensile Strength, lb. per sq. in.	Minimum Elongation in 10 in., per cent
Diameter, in.	A.w.g. Number		
0.460 to 0.290	0000 to 1	36 000	30
0.289 to 0.103	2 to 10	37 000	25
0.102 to 0.021	12 to 24	38 500	20
0.020 to 0.012	25 to 28	39 000	15
0.011 to 0.003	29 to 40	40 000	10

(*d*) *Rejection.*—A coil or reel shall be rejected if the average diameter obtained from the measurements made in accordance with Paragraph (*b*), or the area calculated in accordance with Paragraph (*c*), is not within the limits specified in Paragraph (*a*).

A coil or reel shall be rejected if any individual measurement of diameter or of area of cross-section is not within twice the limits of Paragraph (*a*).

PHYSICAL PROPERTIES AND TESTS

Tensile Properties.

8. (*a*) Each solid conductor and each strand previous to stranding shall be so drawn and annealed that after tinning it shall conform to the values in Table III.

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[1] 1927 Book of A.S.T.M. Standards, Part I, p. 561.

After stranding, the tensile strength of each strand shall not exceed that specified in Table III by more than 5 per cent and the minimum elongation in 10 in. shall not be less than that specified in Table III by more than 5 per cent.

(*b*) For nominal diameters between listed sizes the requirements shall be those of the next larger sizes indicated in Table III.

Tension Tests. 9. (*a*) *Method of Test.*—Tension tests shall be made on fair samples and the elongation shall be determined as the permanent increase in length, due to the breaking of the wire in tension, measured between bench marks originally 10 in. apart. The specimen shall break between the bench marks and not closer than 1 in. to either mark.

(*b*) *Number of Tests.*—Samples shall be taken in accordance with Section 24.

(*c*) *Retests and Rejections.*—If upon testing a sample from a coil, reel or spool of wire, the results are found to be above the stated value for tensile strength or below the stated value for elongation, tests upon two additional samples will be made and the average of the three tests shall determine acceptance or rejection.

Conductivity. 10. The conductivity of the conductors after tinning shall be not less than the following values:

DIAMETER, IN.	A.W.G. NUMBER	CONDUCTIVITY, PER CENT
0.460 to 0.290	0000 to 1	97.65
0.289 to 0.103	2 to 10	97.15
0.102 to 0.021	12 to 24	96.15
0.020 to 0.012	25 to 28	94.15
0.011 to 0.003	29 to 40	93.15

NOTE.—The above values for conductivity are based on the International Annealed Copper Standard. (See Appendix.)

Tinning Test. 11. (*a*) The continuity of the tin coating of each sample before stranding or insulating shall be determined by the sodium polysulfide test which shall be made in accordance with the requirements of Sections 4 to 10 of the Standard Specifications for Tinned Soft or Annealed Copper Wire for Rubber Insulation (Serial Designation: B 33) of the American Society for Testing Materials.[1]

(*b*) *Number of Tests.*—Samples shall be taken in accordance with Section 24.

(*c*) *Retests and Rejections.*—If the specimens tested in accordance with Paragraph (*a*) shows any signs of blackening, two more specimens shall be tested. If one of these two additional specimens shows any blackening, that coil or reel shall be rejected. If both specimens are free from any signs of blackening, the coil or reel shall be accepted. If more than 10 per cent of the samples in the entire order fail, all of the wire shall be rejected. If 10 per cent or less of the samples in the entire lot fail, each coil, reel or length may be tested and accepted or rejected upon the results of the individual tests.

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[1] 1927 Book of A.S.T.M. Standards, Part I, p. 561.

(*B*) INSULATION[1]

Workmanship.

12. (*a*) The insulation shall consist of a properly vulcanized rubber compound which shall be homogeneous in character, tough, elastic and applied concentrically about the conductor and shall fit tightly thereto. Where the insulation is applied in more than one layer, adjacent layers shall be vulcanized into a homogeneous mass.

(*b*) Tape used over insulation during vulcanization will be accepted as a tape under these specifications provided it conforms to the requirements of Sections 45 to 48, inclusive.

(*c*) Where repairs or joints are made in the insulation, the work shall be done in such manner that the repaired part of the joint, and all parts affected in the process, shall be as strong and durable electrically and mechanically as the remainder of the insulation and shall not exceed the limitations on thickness imposed by Section 17.

MANUFACTURE

Composition.

13. (*a*) The insulation shall contain exclusively the best quality Hevea rubber which has not previously been used in a rubber compound, solid waxy hydrocarbons, suitable mineral matter and sufficient sulfur to properly vulcanize the compound.

(*b*) The rubber shall be thoroughly washed and dried before being mixed with the other ingredients.

(*c*) The mineral matter shall be dry and free from organic materials.

(*d*) The waxy hydrocarbons used shall be solid at 54° C. and shall be free from saponifiable matter.

(*e*) *Contamination.*—Contamination of the compound, such as by the use of impregnated tapes, will not excuse the manufacturer from conforming to these specifications.

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[1] Part (*B*), Insulation, Sections 12 to 44, inclusive, of these specifications conform in substance but not in form with the Specifications for 30-per-cent Rubber Insulation for Wire and Cable for General Purposes (A.S.A. No.: C 8*d* 1 - 1928), approved as Tentative American Standard by the American Standards Association, except Sections 12 (*b*) and 23, which have been added.

CHEMICAL PROPERTIES

Quantitative Requirements.

14. The insulation after vulcanization shall conform on analysis to the following requirements expressed as percentages, by weight, of the whole sample:

	MAXIMUM	MINIMUM
Rubber, per cent	33	30
Waxy Hydrocarbons, per cent	4	..
Free Sulfur, per cent	0.7	..

	30-PER-CENT RUBBER[a]		33-PER-CENT RUBBER[a]	
	MAXIMUM	MINIMUM	MAXIMUM	MINIMUM
Saponifiable Acetone Extract, per cent	1.35	0.55	1.50	0.60
Unsaponifiable Resins, per cent	0.45	....	0.50	....
Chloroform Extract, per cent	0.90	....	1.00	....
Alcoholic Potash Extract, per cent	0.55	....	0.60	....
Total Sulfur[b], per cent	2.10	....	2.30	...

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[a] For percentages between 30 and 33, the limits shall be in proportion to the percentage of rubber found.

[b] The limitation on total sulfur may be omitted at the option of the purchaser.

Qualitative Requirements.

15. (*a*) The acetone solution shall not fluoresce and the acetone extract (60 cc.) shall not be darker than a light straw color.

(*b*) The hydrocarbons shall be solid, waxy and not darker than a light brown.

(*c*) The chloroform extract (60 cc.) shall not be darker than a straw color.

PHYSICAL PROPERTIES

Physical Properties.

16. The insulation shall conform to the following requirements as to physical properties:

	MAXIMUM	MINIMUM
Tensile Strength, lb. per sq. in	..	1000
Set in 2 in. gage length, in	$\frac{3}{8}$	....
Elongation at rupture, in	..	2 to 9
Specific gravity, 30-per-cent rubber	..	1.75[a]
Specific gravity, 33-per-cent rubber	..	1.67[a]

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[a] For percentages between 30 and 33, the specific gravity limit shall be in proportion to the percentage of rubber found

THICKNESS

Thickness.

17. The average thickness of the insulation shall be not less than that given in Table IV. The thickness of the insulation at the thinnest part shall be not more than 10 per cent less than the specified thickness, but in no case shall such 10 per cent allowance exceed 0.031 in.

ELECTRICAL PROPERTIES

High Voltage Test.

18. Each coil, reel, or length of wire or cable, after vulcanization and before the application of any covering other than tape or braid used in vulcanization shall successfully withstand the application of an alternating voltage of not less than that given in Table V for a period of 5 minutes.

TABLE IV.—THICKNESS OF INSULATION.

Thickness in sixty-fourths of an inch

(AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS STANDARD NO. 30)

Size of Conductor		Working Pressure, Volts, Direct or Alternating Commercial Power Frequencies											
A. w. g. Numbers or Circular Mils	sq. mm.	600 or less	750	1500	2500	3500	5000	6000	7000	8000	9000	10000	11000
No. 14 to No. 8	2.08 to 8.37	3	4	6	8	10	12	14	16	18	20	22	24
No. 7 to No. 2	10.6 to 33.6	4	5	7	9	10	12	14	16	18	20	22	24
No. 1 to No. 0000	42.4 to 107	5	6	8	10	10	12	14	16	18	20	22	24
250 000 to 500 000 cir. mils	127 to 253	6	8	9	10	11	12	14	16	18	20	22	24
550 000 to 1 000 000 cir. mils	279 to 507	7	9	10	10	12	12	14	16	18	20	22	24
1 250 000 to 2 000 000 cir. mils	633 to 1013	8	10	10	10	12	14	16	18	18	20	22	24

NOTE.—The thickness of insulation (on each conductor in the case of multiple conductor cables) shall be based on the highest r. m. s. voltage between the conductor and the outside of its insulation.

For an intermediate size, the thickness shall be that of the next larger size.

TABLE V.—ALTERNATING TEST VOLTAGE IN KILOVOLTS.

Size of Conductor, A. w. g. Numbers or Circular Mils	Working Pressure, Volts, Direct or Alternating Commercial Power Frequencies											
	600 or less	750	1500	2500	3500	5000	6000	7000	8000	9000	10 000	11 000
No. 14 to No. 8	3	4	6	8	10	13	16	19	18	20	22	24
No. 7 to No. 6	3.5	5	7	9	10	13	16	19	18	20	22	24
No. 5 to No. 2	3.5	5	7	9	10	13	16	19	22	25	28	31
No. 1 to No. 0000	3.5	6	8	10	10	13	16	19	22	25	28	31
250 000 to 500 000 cir. mils	4	8	9	10	11.5	13	16	19	22	25	28	31
550 000 to 1 000 000 cir. mils	4	9	10	10	13	13	16	19	22	25	28	31
1 250 000 to 2 000 000 cir. mils	4	10	10	10	13	16	19	22	22	25	28	31

NOTE.—For an intermediate size or an intermediate working voltage, the test voltage shall be that of the next larger size, or working voltage listed.

Insulation Resistance.

19. Each coil, reel, or length of wire or cable after being subjected to the high voltage test specified in Section 18 shall have an insulation resistance not less than that given in Table VI.

METHODS OF TESTING

CHEMICAL ANALYSIS

Sampling.

20. Samples for chemical analysis shall be taken after vulcanization, before being contaminated incidental to manufacture by the impregnating compound, and after the material has passed all physical and electrical tests. The samples shall be taken at the option of the purchaser. The purchaser shall assure himself that all samples are

free from contamination and change due to torch heating. Wherever practicable, samples shall be taken at a distance of at least 3 ft. from the end of the wire.

TABLE VI.—INSULATION RESISTANCE, MEGOHMS-1000 FT. AT 60° F. (15.5° C).[a]

Size of Conductor, A. w. g. Numbers or Circular Mils	Thickness of Insulation in Sixty-fourths of an Inch							
	2	3	4	5	6	7	8	10
No. 18	8400	10 800	12 900	14 800	15 800	16 900	18 000	19 800
No. 16	7400	9 500	11 400	12 700	14 000	15 000	16 100	18 000
No. 14	....	8 100	9 800	11 400	12 400	13 500	14 000	16 100
No. 12	....	7 100	8 400	9 800	10 800	11 900	12 700	14 500
No. 10	....	6 050	7 150	8 400	9 500	10 600	11 400	12 700
No. 8	....	4 500	5 550	5 600	7 650	8 700	9 200	10 800
No. 6	....	....	4 500	5 550	6 350	7 150	7 650	9 200
No. 4	....	....	3 950	4 500	5 300	6 050	6 600	7 650
No. 2	....	....	3 450	3 950	4 500	5 000	5 550	6 600
No. 1	....	....	3 150	3 450	3 950	4 500	5 300	6 050
No. 0	....	....	....	3 150	3 700	4 200	5 000	5 550
No. 00	....	....	....	2 900	3 450	3 950	4 500	5 000
No. 000	....	....	....	2 650	3 150	3 450	3 950	4 500
No. 0000	....	....	....	2 400	2 900	3 150	3 450	4 200
250 000 cir. mils	....	....	....	2 100	2 500	3 050	3 300	3 850
350 000 cir. mils	....	....	....	1 850	2 250	2 500	2 750	3 550
500 000 cir. mils	....	....	....	1 600	2 000	2 100	2 500	3 050
750 000 cir. mils	....	....	....	....	....	1 700	2 100	2 500
1 000 000 cir. mils	....	....	....	....	....	1 600	1 700	2 100
1 250 000 cir. mils	....	....	....	....	....	....	1 700	2 000
1 500 000 cir. mils	....	....	....	....	....	....	1 600	1 700
1 750 000 cir. mils	....	....	....	....	....	....	1 450	1 600
2 000 000 cir. mils	....	....	....	....	....	....	1 050	1 450

Size of Conductor, A. w. g. Numbers or Circular Mils	Thickness of Insulation in Sixty-fourths of an Inch						
	12	14	16	18	20	22	24
No. 18	21 400	22 700	23 800	24 800	25 900	26 400	27 200
No. 16	19 300	20 900	21 900	23 000	23 800	24 600	25 300
No. 14	17 700	18 700	20 100	20 900	21 600	22 700	23 200
No. 12	15 800	17 200	18 000	19 000	19 800	20 600	21 400
No. 10	14 000	15 300	16 400	17 200	18 000	18 700	19 500
No. 8	11 600	12 700	13 700	14 500	15 300	16 100	16 600
No. 6	10 300	11 100	12 100	12 900	13 500	14 300	14 800
No. 4	8 700	9 800	10 600	11 400	11 900	12 700	13 200
No. 2	7 650	8 400	9 000	9 800	10 300	11 100	11 600
No. 1	7 150	7 650	8 400	9 200	9 800	10 300	10 800
No. 0	6 350	7 150	7 900	8 400	9 000	9 500	10 000
No. 00	5 550	6 600	7 150	7 900	8 400	9 000	9 500
No. 000	5 300	6 050	6 600	7 150	7 650	8 200	....
No. 0000	5 000	5 550	6 050	6 600	7 150	7 650	....
250 000 cir. mils	4 600	5 300	5 800	6 350	6 750	....	....
350 000 cir. mils	4 100	4 500	5 000	5 550	5 950	....	....
500 000 cir. mils	3 550	3 950	4 500	4 750	....	....	....
750 000 cir. mils	2 750	3 300	3 700	4 100	....	....	....
1 000 000 cir. mils	2 500	2 900	3 300	....	....	....	....
1 250 000 cir. mils	2 250	2 650	3 050	....	....	....	....
1 500 000 cir. mils	2 100	2 500	....	....	....	....	....
1 750 000 cir. mils	2 000	2 400	....	....	....	....	....
2 000 000 cir. mils	1 700	2 250	....	....	....	....	....

[a] This table is based on a constant, $K = 21\,120$ in the following formula:

$$R = K \log_{10} \frac{D}{d};$$ where R = resistance in megohms-1000 ft., K = constant,

D = diameter over insulation, on each conductor, and d = diameter over conductor.

NOTE.—For an intermediate size, the insulation resistance shall be that of the next larger size.

Procedure. 21. The insulation shall be analyzed in accordance with (*B*) Complete Procedure as described in the Tentative Methods of

Chemical Analysis of Rubber Products (Serial Designation: D 297 – 28 T) of the American Society for Testing Materials.[1]

Rejection and Retests.

22. The purchaser may make a chemical analysis on any one of the samples selected as described in Section 20 to determine if the compound conforms to the requirements of Sections 14 and 15. Failure of any sample selected to conform to the requirements shall be sufficient cause for rejecting the wire which that sample represents, except in the case of failure to conform to the requirements for either or both free sulfur and chloroform extract. In case of such failure, the coil from which the sample was taken shall be rejected and two additional samples shall be selected from the remainder of the order. The remainder of the order shall be accepted if both samples so selected conform to the requirements for free sulfur or chloroform extract. The entire order shall be rejected if either sample fails.

SPECIFIC GRAVITY

Specific Gravity.

23. The specific gravity shall be determined in accordance with Section 27 of the Tentative Methods of Chemical Analysis of Rubber Products (Serial Designation: D 297 – 28 T) of the American Society for Testing Materials.[1]

TENSION, SET AND ELONGATION

Sampling for Tests.

24. (*a*) When an order calls for less than 500 ft., physical tests may be waived at the option of the purchaser.

(*b*) When an order calls for 500 ft. or more, samples for purposes of test shall be taken from 10 per cent of the coils, reels or lengths, but in any case at least one sample shall be taken.

Test Specimen.

25. (*a*) *Size.*—The test specimen may be the entire section of the insulation in the case of small wires, or, in the case of a large wire or cable, either a segment of a section cut with a sharp knife held tangentially to the conductor or a shaped specimen cut out with a standard die. The test specimen shall be as free as possible from surface incisions and imperfections. There shall be no limit to the cross-section of the test specimen, except as restricted by the capacity of the testing machine.

NOTE.—The removal of the rubber insulation can be greatly accelerated and in most cases a test specimen which is an entire section can be obtained free from surface incisions and imperfections by means of metallic mercury. The mercury should be introduced at one end of the sample between the insulation and the tinned surface of the conductor, and the sample inclined on a support with the end to which the mercury is applied at the top. The separation of the rubber insulation results from the amalgamation of the tin of the conductor with the mercury. The amalgamation is assisted by first immersing and rubbing the tinning on the exposed end of the conductor in the mercury.

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[1] See p. 1072.

(*b*) *Condition and Age.*—Specimens shall not be heated, immersed in water or subjected to any mechanical or chemical treatment not specifically prescribed in these specifications. No tests shall be made within 48 hours after vulcanization unless agreed to by the manufacturer.

(*c*) *Buffing.*—In the event of any irregularities on the surface of the test specimen, it shall be made smooth and of uniform thickness within 5 per cent of the original thickness by buffing, except when large strands are used, in which case the rubber sample shall be buffed sufficiently to remove all corrugations.

Calculation of Area.

26. Calculation of the area of the test specimens shall be made as follows:

(*a*) Where the total cross-section of the insulation is used, the area shall be taken as the difference between the area of the circle whose diameter is the minimum average outside diameter of the insulation and the area of the conductor. The area of a stranded conductor shall be figured from its maximum diameter.

(*b*) Where a slice cut from the insulation by a knife held tangent to the wire is used, and the slice so cut has the cross-section of a segment of a circle, the area shall be calculated as that of the segment of a circle whose diameter is that of the insulation. The height of the segment is the wall of insulation on the side from which the slice is taken. (The values may be obtained from a table giving the areas of segments of a unit circle for the ratio of the height of the segment to the diameter of the circle.)

(*c*) Where the cross-section of the slice is not a segment of a circle, the area shall be calculated from a direct measurement of the volume or from the specific gravity and the weight of a known length of the specimen having a uniform cross-section.

(*d*) Where a portion of a sector of a circle has to be taken where the conductor is large and the insulation thin, the area shall be calculated as the thickness times the width. (This applies either to a straight test piece or one stamped out with a die, and assumes that corrugations have been removed by buffing.)

(*e*) Where a portion of a sector of a circle has to be taken where the conductor is large and the insulation thick, the area shall be calculated as the proportional part of the area of the total cross-section.

Temperature at Test.

27. Physical tests shall be made at a room temperature not less than 65° F. (18.3° C.) nor more than 90° F. (32.2° C.) and the test

specimen shall have been kept at the room temperature not less than 30 minutes prior to the test.

Testing Machine.

28. The testing machine shall be power-driven and preferably of the pendulum type. The machine shall be accurate within 1 per cent of the breaking load. A spring balance type of apparatus may be used if provided with a device which will indicate the actual maximum load at which rupture takes place and if provision is made to prevent recoil of the spring.

Tension Test Procedure.

29. A test specimen which has not previously been tested for set or elongation and having a length of not less than 6 in., and marked with gage marks 2 in. apart, shall be placed in the jaws of the testing machine with a maximum distance between jaws of 4 in. The specimen shall be stretched at the rate of 20 in. per minute (jaw speed) until it breaks. The test specimen shall break between the gage marks and the tensile strength shall be calculated upon the area of the original sample.

Set Test Procedure.

30. A second test specimen having a length of not less than 6 in. and marked with gage marks 2 in. apart, shall be placed in the jaws of the testing machine with a maximum distance between jaws of 4 in. The specimen shall be stretched at the rate of 20 in. per minute (jaw speed) until the gage marks are 6 in. apart. The test specimen shall then be released within 5 seconds and the distance between gage lines shall be determined one minute after the beginning of release. The set is the difference between this length and the original 2-in. gage length.

Elongation Test Procedure.

31. After the determination of the set in accordance with Section 30 the same specimen shall be placed in the jaws of the testing machine with a maximum distance between jaws of 4 in. and stretched at the rate of 20 in. per minute (jaw speed) until the specimen breaks. The test specimen shall break between the bench marks.

Retests.

32. If a specimen fails to conform to any one of the requirements for tensile strength, set or elongation specified in Section 16, two additional specimens shall be taken from the same sample and the average of the results shall determine whether or not the material conforms to the requirements.

Rejection.

33. When ten or more samples are selected in any inspection lot, all coils, reels or lengths shall be rejected if more than 10 per cent of the samples fail. If 10 per cent or less fail, each coil, reel or length may be tested and shall be accepted or rejected upon the results of such individual tests. Where the number of samples selected in any inspection lot is less than ten, all coils, reels or lengths shall be rejected if more than 20 per cent of the samples fail. If 20 per cent or less fail, each coil, reel or length may be tested and shall be accepted or rejected upon the result of such individual tests.

THICKNESS

Apparatus. 34. The thickness measurements may be made with any type of micrometer reading to 0.001 in., suitable for measurements of this character.

Number of Measurements. 35. Where the lot of wire to be inspected consists of two coils or reels or less, at least one determination of the thickness shall be made on each coil or reel. Where the lot consists of more than two coils or reels and less than 20 coils or reels, at least one determination of the thickness shall be made on each of two coils or reels taken at random. If the lot consists of 20 or more coils or reels, not less than 10 per cent of the coils or reels shall be selected at random and at least one determination of the thickness made on each coil or reel so selected.

Procedure. 36. The average thickness of the insulation shall be taken as one-half the difference between the mean of the maximum and minimum diameters measured at any one point and the average diameter of the conductor measured at the same point. The minimum thickness shall be taken as the difference between a measurement made over the conductor plus the thinnest wall and the diameter of the conductor. (The first measurement is made by "slicing off" the heavier side of the insulation.)

In the case of multiple-conductor cable, the measurements shall be made on the individual wires before being cabled.

Rejection. 37. If the thickness of the insulation of any coil or reel is found to be less than the specified value, that coil or reel shall be rejected and a thickness measurement on each of the remaining coils or reels shall be made.

ELECTRICAL TESTS

Place. 38. Electrical tests of wire and cable shall be made at the place of manufacture.

High Voltage Test. 39. The high voltage test shall be made with alternating potential from a transformer and generator of ample capacity and in no case less than 5 kva. The frequency of the test voltage shall be not greater than 100 cycles and shall have a wave shape approximating as closely as possible a sine curve.

Rate of Application. 40. The initially-applied voltage shall be not greater than the rated voltage and the rate of increase shall be approximately uniform and not over 100 per cent in 10 seconds nor less than 100 per cent in 60 seconds.

Immersion in Water. 41. (*a*) The outer surface of the insulation of complete insulated wires and cables shall be grounded while being electrically tested.

If the insulation is not provided with a conducting covering, and if the covering is not liable to injury by water, the ground shall be obtained by immersing the insulated wire or cable in water for at least 12 hours and testing at the end of that period while immersed. If the outer covering is susceptible to injury by immersion, the insulated conductor shall be tested before the application of such covering.

(*b*) In the case of multiple-conductor cables, without waterproof overall jacket of insulation, no immersion test should be made on finished cables, but only on the individual conductors before assembling.

TABLE VII.—TEMPERATURE COEFFICIENTS.

Temperature		Temperature Coefficient	Temperature		Temperature Coefficient
Deg. Fahrenheit	Deg. Centigrade		Deg. Fahrenheit	Deg. Centigrade	
46	7.8	0.69	61	16.1	1.03
47	8.3	0.71	62	16.7	1.05
48	8.9	0.73	63	17.2	1.08
49	9.4	0.75	64	17.8	1.11
50	10.0	0.77	65	18.3	1.14
51	10.6	0.79	66	18.9	1.17
52	11.1	0.81	67	19.4	1.20
53	11.7	0.83	68	20.0	1.23
54	12.2	0.85	69	20.6	1.26
55	12.8	0.88	70	21.1	1.30
56	13.3	0.90	71	21.7	1.33
57	13.9	0.92	72	22.2	1.37
58	14.4	0.94	73	22.8	1.40
59	15.0	0.97	74	23.3	1.44
60	15.6	1.00	75	23.9	1.48

Application of Voltage.

42. (*a*) *Single-Conductor Cables.*—Single-conductor cables shall be tested between conductor and sheath or water in which they are immersed.

(*b*) *Multiple-Conductor Cables.*—If a multiple-conductor cable is rated at the same operating voltage between conductor and sheath or water as between conductors, each conductor shall be tested against the other conductors in the cable and against the sheath or water, at the test voltage prescribed for that rated voltage. If a cable is rated at a voltage between conductors and ground different from that between conductors, the test between conductors shall be based upon the rated voltage between conductors and the test between each conductor and sheath or water, shall be based on the rated voltage between conductors and sheath or water.

The several tests may be made by any arrangement of testing transformers suitable for the prescribed tests, such as one or more transformers supplied from a single-phase source or three transformers connected in star and supplied from a three-phase source.

Insulation Resistance. 43. (*a*) The insulation resistance shall be measured after the high-voltage test has been made and while the wire or cable is still immersed in water. The measurement shall be made after one-minute electrification with a continuous e.m.f. of from 100 to 500 volts, the conductor being maintained negative to the water. The temperature of the water shall be within the limits given in Table VII.

Temperature Coefficient. (*b*) If the temperature at which the insulation resistance was measured differs from 60° F. (15.5° C.), the resistance shall be reduced to that at 60° F. (15.5° C.) by multiplying the measured value by the coefficient in Table VII corresponding to the temperature at which the measurement was made.

Rejection. 44. Each coil, reel or length which fails to comply with the electrical requirements specified in Sections 18 and 19 shall be rejected.

(*C*) RUBBER-FILLED CLOTH TAPE

Material. 45. The tape shall be made from cotton cloth having a weight of not less than one pound per four yards with a width of 36 in. and not less than 56 by 60 picks per inch, and shall be thoroughly filled with a rubber compound.

TABLE VIII.—WIDTH AND OVERLAP FOR RUBBER-FILLED CLOTH TAPE.

Diameter Over Insulation, in.	Width, Maximum, in.	Overlap, Minimum, in.
2.00	5	$\frac{1}{2}$
1.75	$4\frac{1}{2}$	$\frac{1}{2}$
1.50	4	$\frac{1}{2}$
1.25	$3\frac{1}{2}$	$\frac{1}{2}$
1.15	$3\frac{1}{4}$	$\frac{1}{2}$
1.00	3	$\frac{1}{2}$
0.88	$2\frac{3}{4}$	$\frac{3}{8}$
0.75	$2\frac{3}{8}$	$\frac{3}{8}$
0.62	2	$\frac{3}{8}$
0.50	$1\frac{3}{4}$	$\frac{3}{8}$
0.38	$1\frac{1}{2}$	$\frac{1}{4}$
0.31	$1\frac{1}{4}$	$\frac{1}{4}$
0.25	1	$\frac{1}{4}$
0.19	$\frac{7}{8}$	$\frac{1}{8}$
0.16	$\frac{3}{4}$	$\frac{1}{8}$

Application. 46. The tape shall be applied helically. The maximum width and minimum overlap shall conform to the values in Table VIII.

Intermediate Diameters. 47. For intermediate diameters the requirements shall be those of the next smaller diameter indicated in Table VIII.

Number of Tests. 48. Samples shall be taken at the option of the purchaser.

(*D*) BRAID

Material. 49. The braid shall be closely woven from cotton thread having not less than two plys and shall be completely impregnated with an insulating waterproof compound and finished with a black insulating compound thoroughly slicked down.

Compound. 50. The compound shall be neither injuriously affected by nor have injurious effect upon the braid at a temperature of 90° C. (194° F.).

Construction. 51. (*a*) The braid shall be so constructed that the tangent of the angle between the cotton thread and the side of the wire shall be not less than 0.70. The values of the closeness constant, *k*, and the thickness of braid, *t*, shall be not less than those in Table IX.

TABLE IX.—CLOSENESS CONSTANT AND THICKNESS OF BRAID.

Diameter Under Braid, in.	Minimum Closeness Constant (*k*).	Minimum Thickness of Braid (*t*), in.
0 to $\frac{7}{32}$ (0 to 0.219)..........	6	0.018
$\frac{8}{32}$ to $\frac{14}{32}$ (0.25 to 0.437).......	6	0.020
$\frac{15}{32}$ to $\frac{20}{32}$ (0.469 to 0.625)......	7	0.025
$\frac{21}{32}$ to $\frac{25}{32}$ (0.656 to 0.781)	8	0.025
$\frac{26}{32}$ (0.812) and greater.........	8	0.032

(*b*) The values given in Table IX shall be based upon the following formulas:

$$A = \frac{\pi p D}{a}$$

$$t = 2d$$

$$k = \frac{abt}{D}\sqrt{1+A^2}$$

where A = tangent of angle between the cotton thread and the side of the wire;

t = thickness of braid in inches;

k = closeness constant;

D = diameter of wire under braid in inches;

a = number of carriers;

b = number of ends per carrier;

p = two times the picks per inch = number of carriers per inch;

d = average diameter of single thread of cotton per inch.

(*c*) The various quantities shall be determined as follows:

D, by a suitable micrometer after removal of the braid;

a and *b*, by examination of the braid;

p, on a 4 in. length of sample after wiping off the outside of the braid with chloroform;

d, by measuring 25 per cent of the total number of threads with a paper micrometer having a foot 0.4 in. in diameter, under a pressure of 50 g. The sample of braid on which the average diameter is determined can be prepared by immersing a 2 in. length of sample in chloroform in a suitable container for 5 minutes, decanting and repeating for 1 minute, and removing and drying it thoroughly by pressing it between cheese cloth.

Number of Tests.

52. Samples shall be taken at the option of the purchaser.

(*E*) INSPECTION

Inspection and Test.

53. (*a*) Inspection shall be made prior to shipment and at the place of manufacture.

(*b*) The manufacturer shall notify the purchaser sufficiently in advance of the completion of the wire or cable to permit of arrangement of inspection.

(*c*) The inspector representing the purchaser shall have free entry at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the wire ordered, except compounding room. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the wire is being furnished in accordance with these specifications.

(*d*) The purchaser at his option may make the various tests on samples in his own laboratory or elsewhere, but such tests shall be made at the expense of the purchaser.

Rehearing.

54. Samples of rejected material shall be preserved for two weeks from date of test report. In case of dissatisfaction with the results of test, the manufacturer may make claim for a rehearing within that time. Sealed duplicate samples may be retained by the manufacturer at his option.

APPENDIX

ANNEALED COPPER STANDARD[1]

The following shall be taken as normal values for standard annealed copper:

(*a*) *Resistance.*—At a temperature of 20° C. the resistance of a wire of standard annealed copper 1 m. in length and of a uniform section of 1 sq. mm. is $\frac{1}{58}$ ohm = 0.017241 ohm.

(*b*) *Density.*—At a temperature of 20° C. the density of standard annealed copper is 8.89 g. per cu. cm.

(*c*) *Temperature Coefficient of Resistance.*—At a temperature of 20° C. the "constant mass" temperature coefficient of resistance of standard annealed copper, measured between two potential points rigidly fixed to the wire, is 0.00393 = 1/254.45 per degree Centigrade.

(*d*) *Resistance Standard of Annealed Copper.*—As a consequence, it follows from (*a*) and (*b*) that at a temperature of 20° C. the resistance of a wire of standard annealed copper of uniform section, 1 m. in length and weighing 1 g. is: $\frac{1}{58} \times 8.89 = 0.15328$ ohm.

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[1] Extracts from American Institute of Electrical Engineers' Standard No. 30, October, 1925.

TENTATIVE SPECIFICATIONS
FOR
COTTON RUBBER-LINED FIRE HOSE FOR PUBLIC AND PRIVATE FIRE DEPARTMENT USE[1]

Serial Designation: D 296 - 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1928.

Scope. 1. These specifications cover 1½, 2, 2½, 3, and 3½-in. single, double or triple-jacketed cotton, rubber-lined fire hose suitable for use in public or private fire departments.

SPECIFICATIONS

MANUFACTURE

Cotton Fabric. 2. (*a*) The jackets shall be well, evenly and firmly made from good cotton, as free from unsightly defects, dirt, knots, lumps and irregularities of twist as is consistent with good manufacturing practice.

(*b*) Each jacket shall be seamless and shall have the fillers woven around the hose throughout its length and the warps interwoven with and covering the fillers. The jackets may be separate or interwoven.

Rubber Lining. 3. (*a*) The lining shall be made of a properly vulcanized rubber compound which will comply with all the tests specified in Sections 6 to 14, inclusive. It shall consist of not less than three calendered sheets in one solid body and shall be lap-jointed with the lap as small and as neat as is consistent with good results.

(*b*) The lining shall be smooth and practically free from pitting and other imperfections and from corrugations.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. C. J. Krieger, Secretary of Sectional Committee on Specifications for Rubber-Lined Fire Hose, functioning under the procedure of the American Engineering Standards Committee, Underwriters' Laboratories, Inc., 109 Leonard St., New York City.

(*c*) The lining shall be of uniform thickness and within the following limits of thickness exclusive of backing:

INTERNAL DIAMETER OF HOSE, IN.	JACKETS	LINING THICKNESS MINIMUM, IN.	LINING THICKNESS MAXIMUM, IN.
1½ and 2	Single and double	0.049	0.065
2½	Single, double and triple	0.058	0.072
3	Double and triple	0.058	0.072
3½	Double and triple	0.072	0.095

Backing. (*d*) *Backing.*—The backing, if used, shall not exceed 0.028-in. in thickness, as measured from the bottom of the corrugations. It need not be of the same composition as the rubber lining, but the adhesion between the rubber lining and the cotton jacket shall conform to the requirements specified in Section 14.

Flexibility. 4. The hose shall be flexible and easily coiled.

Workmanship. 5. The character of the workmanship shall be such as is incident to good manufacturing practice.

CHEMICAL PROPERTIES

Chemical Analysis. 6. The chemical tests required by the following chemical requirements shall be made in accordance with the methods of testing described in Sections 22 to 35, inclusive.

Chemical Composition. 7. The rubber lining shall on chemical analysis conform to the following requirements as to chemical composition; all percentages shall be calculated on the weight of the total compound.

	MINIMUM, PER CENT	MAXIMUM, PER CENT
Organic Acetone Extract	..	3
Alcoholic-Potash Extract	..	1
Chloroform Extract	..	2.25
Ash (including carbon black)	50	57
Total Sulfur (excluding barytes)	..	3
Free Sulfur	0.5	..

PHYSICAL PROPERTIES

Methods of Testing. 8. The tests necessary to determine the physical properties which are specified in the following sections shall be made in accordance with the methods of testing described in Sections 36 to 51, inclusive.

Sampling. 9. A sample not less than 8 in. in length shall be taken from each lot of 1000 ft. or fraction thereof of hose for the tests specified in Sections 10 to 14, inclusive. All test specimens should be cut transversely from the sample, whenever possible.

Tensile Strength Within 60 Days. 10. (*a*) The tensile strength shall not be less than 1600 lb. per sq. in. when tested within 60 days of the date of final vulcanization.

(*b*) *Elongation.*—The elongation when rupture occurs in making the tensile strength test specified in Paragraph (*a*) shall be such that the original 2-in. gage length shall stretch to not less than 12 in.

Tensile Strength Within One Year.

11. (*a*) The tensile strength shall not be less than 1200 lb. per sq. in. when tested within one year of the date of final vulcanization.

(*b*) *Elongation.*—The elongation when rupture occurs in making the tensile strength test specified in Paragraph (*a*) shall be such that the original 2-in. gage length shall stretch to not less than 10 in.

Permanent Elongation.

12. (*a*) The permanent elongation or set, for tests made within 60 days, of samples cut transversely following a stretch from 2 to 10 in. shall not exceed 25 per cent and shall not exceed 30 per cent for samples cut longitudinally.

(*b*) The permanent elongation or set, for tests made within 1 year, of samples cut transversely following a stretch from 2 to 8 in. shall not exceed 25 per cent and shall not exceed 30 per cent for samples cut longitudinally.

Friction Test.

13. The adhesion between the lining and the cotton jackets shall be such that the rate of separation of a $1\frac{1}{2}$-in. strip of lining from the jackets shall not be greater than 1 in. per minute under a weight of 12 lb.

Life Test.

14. After subjection to a dry heat of 158° F. (70° C.) ±2° F. (1.1° C.) for a period of four successive days of 24 hours each and then placed in air at room temperature for 24 hours, the tensile strength shall not be less than 900 lb. per sq. in.

HYDROSTATIC TEST REQUIREMENTS

Hydrostatic Pressure Tests.

15. (*a*) Each length of single-jacketed hose shall be subjected to a hydrostatic pressure of 300 lb. per sq. in. for 5 seconds without leaking in the hose or at the couplings or breaking any threads in the jackets. Each length of double or triple-jacketed hose shall be subjected to a hydrostatic pressure of 400 lb. per sq. in. for 5 seconds without leaking in the hose or at the couplings, or breaking any threads in the jackets.

Elongation.

(*b*) *Elongation.*—The elongation of the hose when tested as specified in Paragraph (*a*), shall not exceed 10 per cent of the length for single-jacketed hose, and 8 per cent for double or triple-jacketed hose measured from an initial pressure of 10 lb. per sq. in.

Twist. (*c*) *Twist.*—The hose, when tested as specified in Paragraph (*a*), shall not twist more than shown in the following table:

INTERNAL DIAMETER OF HOSE, IN.	JACKETS	TWIST, DEG. PER FT.
1½ and 2	Single	50
2½	Single	25
1½ and 2	Double	29
2½, 3 and 3½	Double and triple	12.5

The twist requirements refer to the final twist, in a direction to tighten, rather than loosen the couplings. No final twist in a direction tending to loosen the coupling shall be permitted.

Warp and Rise. (*d*) *Warp and Rise.*—The hose, when tested as specified in Paragraph (*a*), shall not warp more than 20 in. from a straight line drawn from center to center of the couplings. Single-jacketed hose shall not rise from the level of the test table more than indicated in the following table, and no rise shall be permitted for double and triple-jacketed hose:

INTERNAL DIAMETER OF HOSE, IN.	JACKETS	PERMISSIBLE RISE, IN.
1½ and 2	Single	7
2½	Single	4

Bursting Strength Tests. 16. A 3-ft. sample in every lot of 3000 ft. or fraction thereof of hose, shall stand without failure, while lying either straight or curved to a radius of 27 in., a hydrostatic pressure as indicated in the following table:

INTERNAL DIAMETER OF HOSE, IN.	JACKETS	REQUIRED PRESSURE, LB. PER SQ. IN.
1½, 2 and 2½	Single	500
1½, 2 and 2½	Double and triple	600
3 and 3½	Double and triple	600

Kink Tests. 17. One full length in every lot of 500 ft. or fraction thereof of hose shall stand without failure, while kinked, a hydrostatic pressure as indicated in the following table:

INTERNAL DIAMETER OF HOSE, IN.	JACKETS	REQUIRED PRESSURE, LB. PER SQ. IN.
1½, 2 and 2½	Single	300
1½ and 2	Double	350
2½	Double and triple	350
3 and 3½	Double and triple	250

Place of Test. 18. All hydrostatic tests shall be performed either at the factory or at the destination, at the discretion of the purchaser. Arrangements for such tests shall be subject to arrangement reached between the manufacturer and purchaser, at the time the order is placed.

DIMENSIONS AND MARKING

Diameter. 19. The hose shall have an internal diameter as shown by a tapered plug gage of not less than $1\frac{1}{2}$, 2, 3, or $3\frac{1}{2}$ in., as ordered. In the case of $2\frac{1}{2}$-in. hose, the internal diameter as measured in this manner shall not be less than $2\frac{9}{16}$ in.

Length. 20. The hose shall be furnished in nominal lengths of 50 ft.

Marking. 21. Beginning at a point not less than 4 ft. from each end, each 50-ft. length of hose shall be stenciled at two places in indelible letters at least 1 in. in height with the name of the manufacturer and the month and year of manufacture.

METHODS OF TESTING

CHEMICAL ANALYSIS[1]

REAGENTS

Reagents. 22. (*a*) *Acetone.*—The acetone shall be chemically pure and shall be freshly redistilled over anhydrous sodium carbonate, using the 56 to 57° C. fraction.

(*b*) *Alcoholic-Potash Solution.*—The alcoholic-potash solution shall be of normal strength. It shall be made by dissolving the required amount of KOH in alcohol which has been purified as follows:

Dissolve 1.5 g. of $AgNO_3$ in 3 cc. of water and add it to 1000 cc. of alcohol. Dissolve 3 g. of KOH in the smallest amount of hot water, cool, add it to the alcoholic-silver nitrate solution, and shake thoroughly. Allow the solution to stand for at least 24 hours, filter, and distill. (Alcohol denatured with 10 per cent by volume of methanol may be used in place of ethyl alcohol.)

(*c*) *Nitric Acid-Bromine Solution.*—The nitric acid-bromine solution shall be prepared by adding a considerable excess of bromine to concentrated HNO_3 and shaking thoroughly.

(*d*) *Zinc-Nitric Acid Solution.*—The zinc-nitric acid solution is made by adding 200 g. of zinc oxide to 1000 cc. of concentrated HNO_3.

(*e*) *Barium Chloride Solution.*—Barium chloride solution shall be made by dissolving 100 g. of crystallized barium chloride in 1 liter of distilled water, and adding two to three drops of concentrated HCl. If there is any insoluble matter or cloudiness, the solution shall be heated overnight on the steam bath and filtered.

Blank Analyses. 23. The purity of all materials shall be checked and determined by blank analyses.

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[1] These methods of chemical analysis are in accordance with the more complete procedure as given in the Tentative Methods of Chemical Analysis of Rubber Products (Serial Designation: D 297 – 28 T) of the American Society for Testing Materials, see p. 1072.

PREPARATION OF SAMPLE

Preparation of Sample

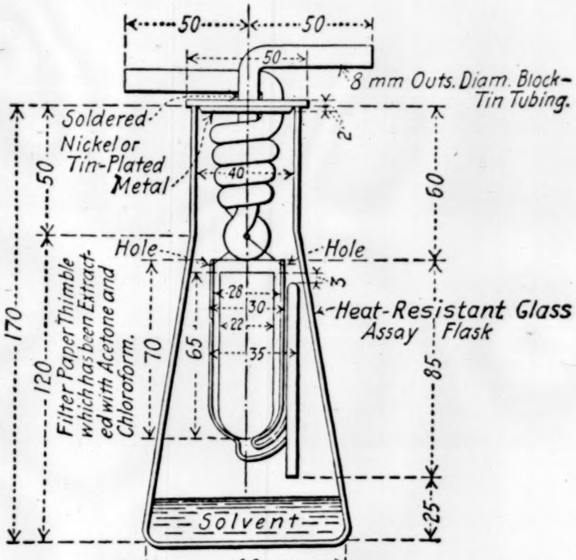
24. Before preparing a sample for analysis the analyst shall by inspection, assure himself that it has not been contaminated. The sample shall be prepared by taking pieces from various parts of the original sample and separating them from foreign matter. The rubber shall be ground to the required fineness on a rubber mill or cut with scissors so as to pass a No. 14 sieve.

METHODS OF ANALYSES

Acetone Extract

Extraction Apparatus.

25. The extraction apparatus used here and for other extractions shall be of the type similar to that shown in Fig. 1. The flask shall be heated so that the period of filling an empty siphon cup with acetone and completely emptying it will be between 2.5 and 3.5 minutes.


50
50
50
8 mm Outs. Diam. Block-Tin Tubing.
Soldered
Nickel or Tin-Plated Metal
2
50
60
40
Hole
Hole
3
170
120
Filter Paper Thimble which has been Extracted with Acetone and Chloroform.
70
65
28
30
22
35
Heat-Resistant Glass Assay Flask
85
25
Solvent
80

(All dimensions in millimeters.)

FIG. 1.—Extraction Apparatus.

Procedure.

26. Place 2 g. of rubber in a thimble made by folding a filter paper so that it will fit in the extraction cup, which is suspended in a weighed extraction flask. Extract the sample continuously for 16 hours, unless the solution in the thimble is still colored at the end of that time, when the extraction shall proceed for a further

period of 4 hours or longer. Carefully note all characteristics of the acetone extract, both when hot and cold. Distill off the acetone on a steam bath, recovering the acetone if desirable, at as low a temperature as possible. Loss of extract by bumping can be avoided by means of a gentle current of air. Care must be taken to avoid allowing the flasks to stand on the steam bath after the solvent has been removed, because appreciable quantities of free sulfur may be lost by so doing. Dry the extraction flask and contents in an air bath for 1 hour at 70° C., cool, and weigh. Keep the sample for future determinations.

$$\text{Percentage of acetone extract} = \frac{\text{Wt. of extract}}{\text{Wt. of sample}} \times 100$$

Chloroform Extract

Chloroform Extract.

27. The rubber sample (see Section 26) is suspended in a second weighed extraction flask and extracted for 4 hours with chloroform. Care should be taken that any small particles of rubber, which are often carried down into the extract, are filtered off. Evaporate off the solvent and dry to constant weight, usually 1 hour at 70° C., cool, and weigh. The color of the chloroform solution should be recorded. Reserve the rubber for extraction with alcoholic potash.

$$\text{Percentage of chloroform extract} = \frac{\text{Wt. of extract}}{\text{Wt. of sample}} \times 100$$

Alcoholic-Potash Extract

Alcoholic-Potash Extract.

28. Dry the rubber from the chloroform extraction at about 70° C. to remove the chloroform, transfer to a 200-cc. Erlenmeyer flask, add 50 cc. of alcoholic-potash solution, and heat under a reflux condenser for 4 hours. Filter into a 250-cc. beaker, wash with two portions of 25-cc. of boiling alcohol; then with three 25-cc. portions of boiling water, and evaporate the filtrate to dryness. Use about 75-cc. of distilled water to transfer the residue to a separatory funnel. Acidify the solution with HCl (10-per-cent), testing with Congo-red paper. Extract with four 25-cc. portions of ether, unless the fourth portion should be colored, when the extraction must be continued until no further quantity can be removed. Unite the ether fractions and wash thoroughly with distilled water until free from acid (two washings are generally sufficient). Filter the ether solution through a plug of absorbent cotton into a weighed flask, wash with ether, evaporate, dry to constant weight at 70° C., cool, and weigh.

$$\text{Percentage of alcoholic-potash extract} = \frac{\text{Wt. of extract}}{\text{Wt. of sample}} \times 100$$

Free Sulfur

29. Add to the flask containing the acetone extract (Section 26), 60 cc. of distilled water and 2 to 3 cc. of bromine, and cover with a watch glass. Allow the flask to stand 30 minutes on the side of the steam bath, then heat cautiously over the direct steam bath until the solution is practically colorless, filter into a 250-cc. beaker, and dilute to about 175 cc. with distilled water. Precipitate with barium chloride and determine in the usual manner. **Free Sulfur.**

$$\text{Percentage of free sulfur} = \frac{\text{Wt. of BaSO}_4 \times 0.1373}{\text{Wt. of sample}} \times 100$$

Subtract the percentage of free sulfur thus determined from the acetone extract (Section 26) and call the result "organic acetone extract."

Total Sulfur

30. (*a*) *Recommended Method.*—Place 0.5 g. of rubber in a porcelain crucible of about 75-cc. capacity, add 15 cc. of the nitric acid-bromine solution, cover the crucible with a watch glass, and let it stand for 1 hour in the cold. Heat for 1 hour on the steam bath, remove the cover, rinse it with a little distilled water, and evaporate to dryness. Add 3 cc. of HNO_3, cover, warm a short time on the steam bath, then let it cool. Carefully add in small portions, by means of a glass spatula, 5 g. of sodium carbonate (weighed to 0.5 g.). The watch glass is to be raised only high enough to permit the introduction of the spatula. The carbonate is allowed to slide down the side of the crucible and is not dropped directly into the acid. Rinse the watch glass with 2 or 3 cc. of hot distilled water and stir the mixture thoroughly with a glass rod. Digest for a few minutes, spread the mixture halfway up the side of the crucible to facilitate drying, and dry on a steam bath. Fuse the mixture by heating over a sulfur-free gasoline flame. **Total Sulfur. Recommended Method.**

(*b*) Place the crucible in an inclined position on a wire triangle and start the ignition over a low flame. The tendency for the organic matter to burn too briskly is controlled by judicious use of the stirring rod with which the burning portion is scraped away from the rest. When part of the mass is burned white, a fresh portion is worked into it until all of the organic matter is destroyed. It is necessary to hold the edge of the crucible with tongs. Toward the last half of the operation the flame should be increased. It is unnecessary to heat the crucible to redness. With care, a crucible can be used for at least 10 to 12 fusions.

(*c*) After a fusion, allow the crucible to cool, place it in a 400-cc. beaker, add sufficient distilled water to cover the crucible (about 125 cc.), and digest on the steam bath for 2 hours, with occasional stirring. If the filtration can not be made on the same day, do not add the water, but allow the fusion to stand overnight.

(*d*) Filter the solution into a covered 400-cc. beaker containing 5 cc. of concentrated HCl, and wash the residue thoroughly with hot water. (A qualitative test of barium can be made on the residue.) Complete the acidification of the filtrate and washings and add 2 cc. of concentrated HCl in excess. Cover the beaker and heat the solution on the steam bath. The total volume of the solution should be 300 cc. The solution must be acid to Congo paper in order to insure the complete destruction of the carbonates. Precipitate with barium chloride and determine the sulfur in the usual manner.

$$\text{Percentage of total sulfur} = \frac{\text{Wt. of } BaSO_4 \times 0.1373}{\text{Wt. of sample}} \times 100$$

Total Sulfur, Alternate Method.

31. (*a*) *Alternate Method.*—When this method is used the total sulfur determined represents the sulfur exclusive of that originally present as barytes or formed from barium salts, if present in the compound.

(*b*) Place a 0.5-g. sample in a 500-cc. Erlenmeyer destruction flask (Pyrex glass). Add 10 cc. of zinc oxide - nitric acid solution and moisten the sample thoroughly. If convenient, the mixture may be allowed to stand overnight. By so doing the sample becomes partly decomposed; this permits the addition of fuming HNO_3 with no danger of ignition of the sample. Add 15 cc. of fuming HNO_3 and whirl the flask rapidly to keep the sample immersed to avoid ignition by too rapid oxidation. With some samples it will be found necessary to cool the flask under a stream of tap water.

(*c*) When the solution of the rubber is complete, add 5 cc. of a saturated water solution of bromine and slowly evaporate the mixture to a foamy sirup.

(*d*) If particles of organic matter remain at the end of the evaporation, add a few cubic centimeters of fuming HNO_3 and re-evaporate as before. Cool, and add a few crystals of potassium chlorate to assist in the oxidation of the sulfur and the decomposition of any nitrates.

(*e*) Place the flask on asbestos gauze and evaporate the mixture to dryness over a Tirrill burner. Then bake the mixture at the highest temperature of the burner until all nitrates are decomposed and no more nitrogen peroxide fumes can be detected. When the baking is complete, cool the flask, add 50 cc. of HCl (1:6) and heat until solution is complete. (In case the original mixture contains barium sulfate or other salts, they will be precipitated at this point with consequent loss of sulfur in the case of the latter. If litharge is present in the mixture, lead salts, not otherwise removed, will be eliminated in the final washings with boiling water.) Filter the solution, dilute to 300 cc., precipitate with barium chloride, and determine the sulfur in the usual manner.

$$\text{Percentage of total sulfur} = \frac{\text{Wt. of BaSO}_4 \times 0.1373}{\text{Wt. of sample}} \times 100$$

Ash

32. *Rapid Method.*—Wrap a 1-g. sample in a filter paper, extract with acetone for 4 hours, and transfer to a weighed, approximately 50-cc. porcelain crucible. Ash the sample in a muffle furnace by heating at the following rate: **Ash, Rapid Method.**

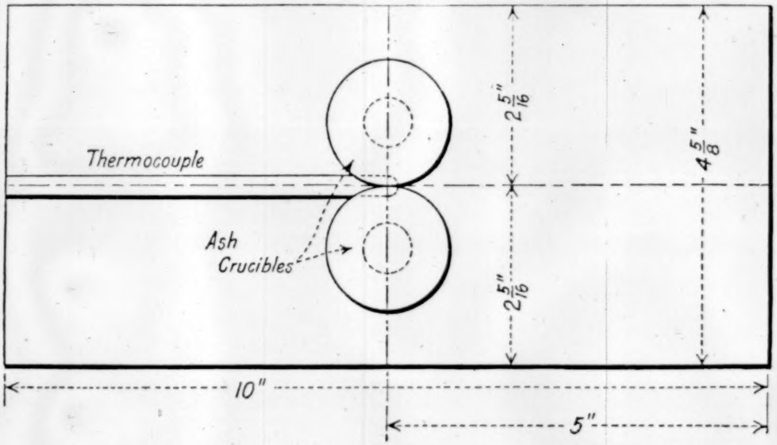


FIG. 2.—Location of Apparatus for Ash Determination (Referee Method).

Time, minutes	0	5	10	15	70	75	80	85	145
Temperature, deg. Centigrade	0	100	200	300	300	400	500	550	550

Remove the crucible from the furnace, cool, and weigh.

$$\text{Percentage of ash} = \frac{\text{Wt. of ash}}{\text{Wt. of sample}} \times 100$$

33. (*a*) *Referee Method.*—In case of disagreement on results as obtained in the Rapid Method described in Section 32, an electric muffle furnace shall be employed for the test. Numbered porcelain crucibles 41 mm. in diameter and 25 mm. in height shall be used. The bottom of the furnace shall be covered by a sheet of asbestos 0.06 in. in thickness, cut to fit. **Ash, Referee Method.**

(*b*) Extract a 2-g. sample with acetone as described in the acetone extraction (see Section 26). Allow the extracted sample to dry at 100° C., cool in a desiccator and weigh. Divide the sample into two parts of equal weight; place each of them in crucibles previously ignited, cool in a desiccator, and weigh. Place the two crucibles, with contents, together (with their tops touching) in the furnace on a line crossing the furnace half-way between its ends, as shown in Fig. 2. Regulate the temperature of the furnace by means of a rheostat so that the temperature corresponds to the curve shown in Fig. 3, with a maximum permissible variation of ±25° C. Measure the temperature with a thermocouple (previously calibrated) enclosed in a quartz tube closed at one end, 6 to 7 mm. in diameter, 0.5 to 1 mm. in thickness, and placed in a horizontal position in contact with the asbestos sheet on the bottom of the furnace, so that the hot junction of the couple is on a line crossing the furnace half-way between its ends, and half-way between the two crucibles, as shown in Fig. 2. Adjust the door of the furnace to conform to the following requirements:

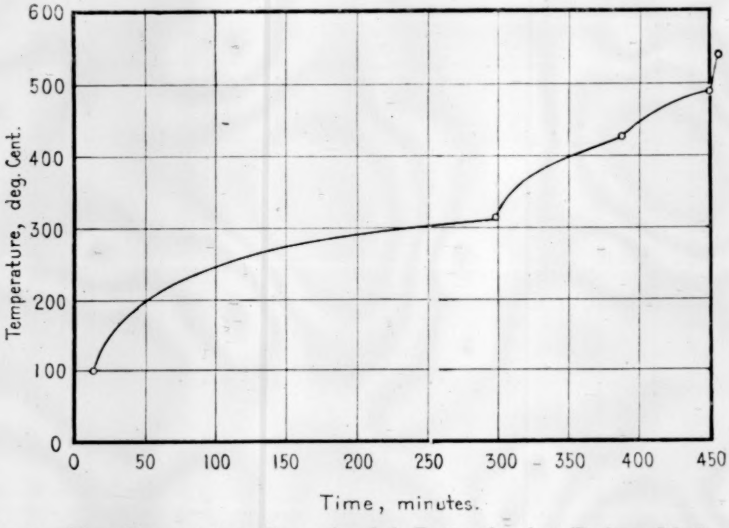


FIG. 3.—Time-Temperature Curve for Ash Determination (Referee Method).

	OPENING
First 400 minutes	½ in.
From 400 to 450 minutes	1½ in.
Balance of period (7 minutes)	wide open

(*c*) At the end of the period of heating, as shown, remove the crucibles from the furnace, cool in a desiccator and weigh.

$$\text{Percentage of ash} = \frac{\text{Wt. of ash}}{\text{Wt. of sample}} \times 100$$

Sulfur in Ash

Sulfur in Ash.

34. Add 3 cc. of nitric acid - bromine solution to the ash (see Section 32), cover with a watch glass and heat for 1 hour, remove the cover, rinse it with a little distilled water, and evaporate to dryness. Complete the determination of sulfur as described in Section 30 (*d*).

Save the insoluble residue, after filtering the solution of the fusion mixture in water, for testing in accordance with Section 35.

Sulfur as Barium Sulfate

Sulfur as Barium Sulfate.

35. The barium sulfate is calculated from the barium in the ash, which is determined as follows: Filter off the insoluble matter after the fusion and extraction described in Section 34, wash back into the original beaker with hot water, dissolve the residue in the beaker and any traces on the filter paper with HCl, and heat the solution on the steam bath. Filter through the same filter as before and wash thoroughly with hot water. Nearly neutralize the solution with NH_4OH, leaving it slightly acid. Saturate the cold solution with H_2S, and when the lead sulfide has settled, filter into a 400-cc. beaker and wash thoroughly. The total volume should be not over 200 cc. Precipitate with H_2SO_4 (10-per-cent) and determine the sulfur in the usual manner. Barium sulfate determined above is assumed to have been added as such. Obviously, if barium carbonate is present, it must be determined in order that an undue correction will not be made.

$$\text{Percentage of sulfur as barium sulfate} = \frac{\text{Wt. of } BaSO_4 \times 0.1373}{\text{Wt. of sample}} \times 100$$

PHYSICAL TESTS

Cutting of Samples.

36. All samples shall be cut transversely unless the diameter of the hose is too small to furnish a test piece of sufficient length, in which case the sample shall be cut longitudinally.

Temperature.

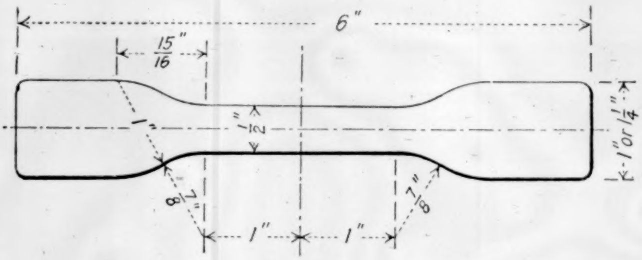
37. All tests of the rubber parts shall be made when possible in a room the temperature of which is not less than 60 nor more than 90° F. In case of a failure obtained when room temperatures are outside of these limits, rejection shall not be made until check tests are made within the specified temperature limits. No tests shall be made, if so desired by the manufacturer, until the article to be tested has been standing at least 48 hours after vulcanization.

Average Reading. 38. Acceptance or rejection shall be based on the average of at least four determinations for each item. In arriving at these averages no weight shall be given to tests which are obviously in error and do not represent true average conditions; for example, cases in which the tensile strength is low on account of a small flaw in the article or the friction is low on account of a small flaw in the friction compound.

(*A*) *Tensile Strength and Elongation at Rupture*

Apparatus. 39. An accurately calibrated testing machine so operated that the jaws separate at a uniform rate of 20 in. per minute, shall be employed in determining the tensile strength and elongation at rupture.

Test Specimen. 40. A section of hose 1 in. in width shall be cut in accordance with Section 36 and the rubber parts shall be carefully separated from the fabric, using benzine, if necessary. The benzine used in this case shall be about 76° Baumé, free from oil. No test shall be performed, if so desired by the manufacturer, until the specimen has been allowed to stand for 1 hour after it has in any way been in contact with benzine. From this 1-in. section of rubber a test specimen, as shown in Fig. 4, which shall be without physical injury shall be cut by a die, see Fig. 5. The specimen as thus prepared shall then be buffed free from corrugations.



(*a*) ½ by 2-in. Specimen.

Fig. 4.—Tensile Strength and Permanent Elongation Test Specimen.

Marking. 41. Gage marks 2 in. apart shall be placed on the reduced section of the test specimen one on each side of the center and 1 in. therefrom. These marks shall be at right angles to the direction of pull of the test specimen in the machine. Great care shall be taken that the marks are not too wide and that at the time of marking, the test specimen shall have been lying for a sufficient length of time to be completely at rest. The marks shall be placed on the unbuffed side of the specimen.

Tensile Strength Tests. 42. (*a*) *Cross-Sectional Area.*—Before the tensile strength tests are made, the width of the test specimen between the gage marks shall be determined. After buffing off the backing or fabric impressions, the thickness shall be determined from the average of four readings, taken at equal points between the gage marks on the test piece by means of a spring-gage micrometer, provided with a $\frac{3}{8}$ in. foot applied under a pressure of 60 g. The cross-sectional area shall be calculated from these determinations.

(*b*) *Procedure.*—After clamping the test specimen in the jaws of the machine the movable jaw shall be so adjusted with the pointer reading zero on the scale that the test piece is just taut but not under tension. The operator shall throw on the current to start the screw and, when ready, throw in the engaging lever to start the jaws. He shall keep the elongation scale pointers opposite the outside edges of the gage marks on the test piece. The tensile strength shall be determined by stretching the test specimen in the testing machine until it breaks. If the test specimen breaks outside the gage marks or in the wider portions of the test specimen and the tensile strength

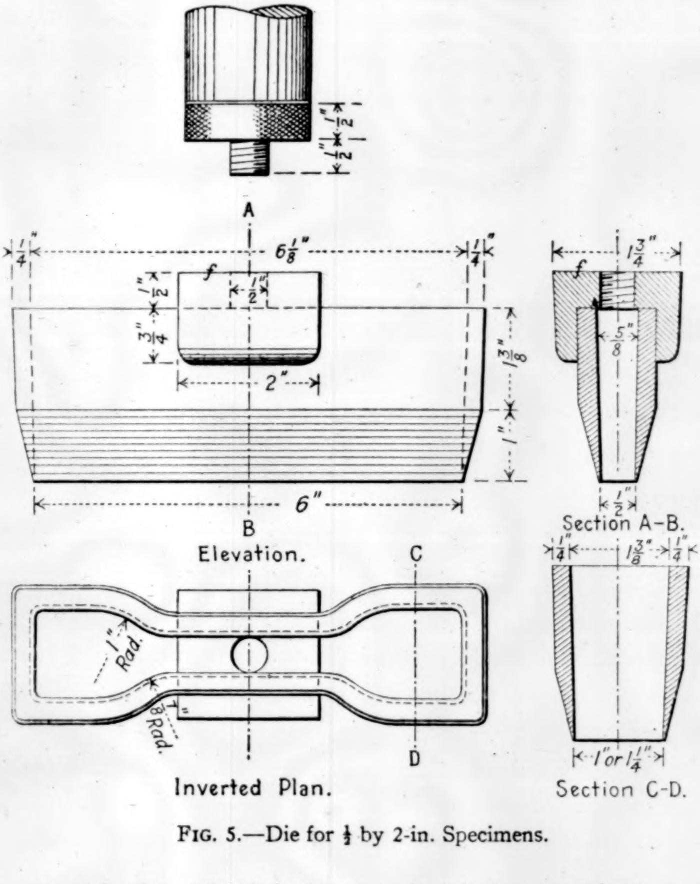

1/2"
1/2"
A
1/4"
6 1/8"
1/4"
f
1/2"
1/2"
3/4"
2"
1 3/8"
1"
6"
B
Elevation.
C
1" Rad.
1/8" Rad.
D
Inverted Plan.
1 3/4"
f
5/8"
1/2"
Section A-B.
1/4"
1 3/8"
1/4"
1" or 1 1/4"
Section C-D.

FIG. 5.—Die for ½ by 2-in. Specimens.

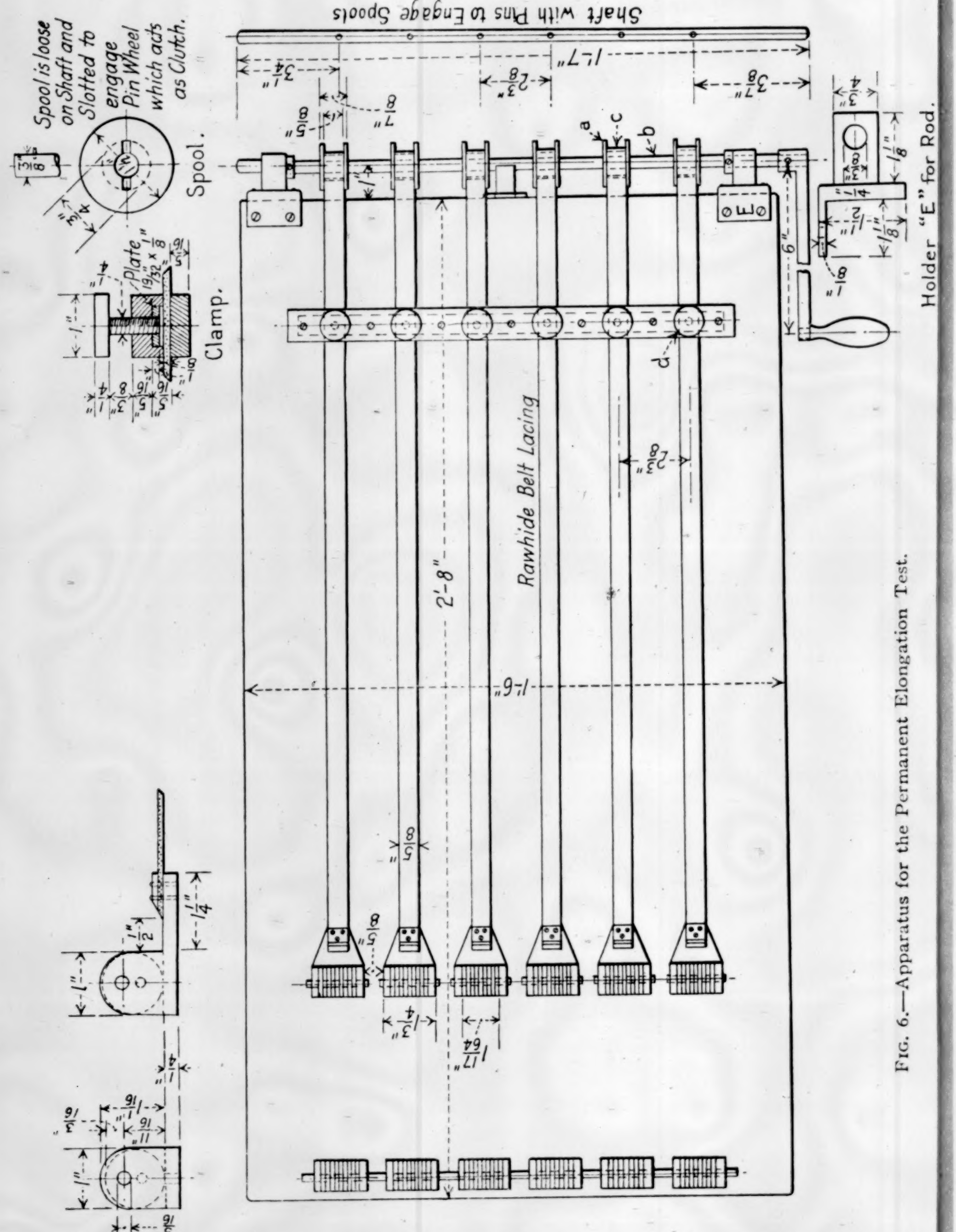

Shaft with Pins to Engage Spools
1'-7"
3 1/4"
2 3/8"
3 7/8"
5/8"
7/8"
1"
a
b
c
d
E
6"
1/8"
1 1/2"
1 1/8"
3/4"
1/4"
4 3/4"
Holder "E" for Rod.
Spool is loose on Shaft and Slotted to engage Pin Wheel which acts as Clutch.
3/8"
4 3/4"
Spool.
Plate 19/32" × 1/8"
1"
1/4"
3/8"
5/16"
5/16"
1/8"
Clamp.
2'-8"
1'-6"
Rawhide Belt Lacing
2 3/8"
5/8"
5/8"
1 3/4"
1 17/64"
1"
1/2"
1 1/4"
1"
3/16"
11/16"
1 1/16"
1/4"
5/16"

FIG. 6.—Apparatus for the Permanent Elongation Test.

is much below that called for in the specifications, it is probable that this specimen is faulty and that another would conform to the requirements. If the piece breaks outside the marks and yet shows a tensile strength above that called for in the specifications it is probable that the piece is faulty and its true tensile strength is higher than indicated. Since its recorded tensile strength exceeds that called for in the specifications it is not necessary to retest.

(*c*) *Calculation.*—From the actual breaking load as read from the scale of the testing machine the tensile strength in pounds per square inch shall be calculated.

Elongation at Rupture. 43. The elongation at rupture shall be determined at the same time and on the same specimen used for the tensile strength test described in Section 42. As the specimen is stretched between the jaws of the machine, the operator shall keep the elongation scale pointers opposite the outside edges of the gage marks on the test specimen. The elongation at rupture shall be measured in inches, and shall include the original 2 in. marked on the specimen.

(*B*) *Permanent Elongation*

Apparatus. 44. For the permanent elongation test, the apparatus shown in Fig. 6 shall be used. The spools, *a*, are free to slide on the shaft, *b*, and are slotted to engage pins, *c*, which act as clutches. The movable grips are attached to strips of leather-belt lacing $\frac{5}{8}$ in. in width which pass through clamps, *d*, and then to the spools, *a*.

Test Specimen. 45. The permanent elongation test shall be made only on specimens which have not been previously tested. The test specimens shall be prepared for testing in accordance with Sections 40 and 41.

Procedure. 46. Six test specimens shall be placed in the grips of the apparatus shown in Fig. 6, one of the spools, *a*, shall be moved along the shaft until it engages the corresponding pin, *c*. After placing the test specimen in the device previous to stretching, the test specimen shall be drawn just taut and the time measured at the instant of beginning of the stretching. All measurements of time shall be taken by means of a stop watch. The shaft shall be revolved until the desired elongation measured between the gage marks on the test specimen is obtained. The clamp, *d*, shall be tightened to hold the specimen in this position, and the spool shifted back so as to disengage the pin. When the test specimen has been held in this position for 10 minutes it shall be released and the time shall again be measured at the moment the specimen is released. This moment is simultaneously the beginning for a ten-minute period of rest. Immediately upon the expiration of the ten-minute rest period the elongation or recovery shall be measured by laying the test specimen upon a smooth surface which is of the temperature of the room and measuring to the outside of the gage marks with a scale graduated to 0.01 in. This operation shall be carried out on each of the test specimens in turn.

Calculation. 47. The difference between the final elongation and the original 2-in. gage length divided by the gage length and expressed as a percentage shall be taken as the permanent elongation.

(*C*) *Friction Test*

Test Specimen. 48. The test specimen shall be 2 in. in width and shall be cut transversely from the hose so as to give a rectangular sample the full circumference of the hose in length when cut through the walls and laid out flat. A strip of lining $1\frac{1}{2}$ in. in width shall be cut out accurately, the cut extending through the lining but not entirely through the cotton jacket. This strip shall be started at one end to the extent of about $1\frac{1}{2}$ in.

Procedure. 49. The free end of the cotton jacket shall be clamped in a stationary grip and the separated rubber lining shall be clamped in a freely suspended grip hanging vertically and to which the specified weight may be attached with suitable provision for supporting and releasing it slowly without jerking. The weight shall be released and the distance through which separation takes place shall be determined after a period of 10 minutes. The friction shall be taken as the rate obtained by dividing the total distances separated in inches (to the nearest 0.01 in.) by the elapsed time in minutes.

Referee Method. 50. (*a*) *Test Specimen.*—In case of disagreement as to the friction test described in Section 50, new test specimens $1\frac{1}{2}$ in. in width shall be cut transversely from the hose so as to give a rectangular sample the full circumference of the hose in length when cut through the walls and laid out flat. One-quarter inch of the rubber lining shall be carefully and cleanly trimmed off on each side of the width for the entire length, without injuring the fabric, leaving a strip of rubber lining 1 in. in width undisturbed on a strip of cover $1\frac{1}{2}$ in. in width. A separation between the lining and the cover of the strip shall be started for about $1\frac{1}{2}$ in.

(*b*) *Procedure.*—The fabric of the test piece shall be fastened by means of a clamp to the power head of the testing machine used for the tensile strength tests, see Section 39. The rubber portion shall be clamped to the recording head without twisting. The machine shal be run at a uniform rate of 2 in. per minute. After separation commences the load shall be constantly watched to see that it does not fall below the specification requirement for a greater total length than 5 per cent of the total length separated. The load may be recorded on an atomatic recording device. The entire friction layer shall be separated.

(*D*) *Life Test*

51. Test specimens for the life test shall be prepared in accordance with Sections 40 and 41. A hole about $\frac{1}{8}$ in. in diameter shall be punched near the end of an enlarged end so that the specimens may be suspended upon a small rod. Specimens so suspended shall be separated by washers at least $\frac{1}{4}$ in. in thickness to permit the free circulation of air between them. This rod with its strips shall be hung in a well-insulated electric oven within which the temperature can be maintained at 158° F. (70° C.) ±2° F. (1° C.). These specimens shall be left in the oven at the specified temperature continuously for four days of 24 hours each. They shall then be removed, allowed to hang in the air at room temperature for 24 hours, after which the tensile strength shall be determined in accordance with Section 42. **Life Test.**

HYDROSTATIC TESTS

52. All hydrostatic tests shall be made with a pump equipped with calibrated gages. **Apparatus.**

53. The increase in pressure shall be at the rate of not less than 300 lb. per sq. in. per minute. The hose under test shall be held under pressure for measurement not more than 2 minutes. **Application of Pressure.**

54. In the tests for elongation, twist, warp and rise the hose shall be stretched out for inspection, connected to the pump and filled with water, leaving the air cock open to allow all air in the hose to escape. The air-cock shall then be closed and a pressure of 10 lb. per sq. in. applied. All original measurements shall be taken at this pressure. After measurements are taken the test pressure shall be applied in accordance with Section 53 without releasing the pressure from the original pressure of 10 lb. per sq. in. **Elongation, Twist, Warp and Rise.**

55. Samples for the bursting-strength test shall be cut from lengths which have not been tested previously to more than 300 lb. per sq. in. for single-jacketed cotton hose and 400 lb. per sq. in. for multiple-jacketed hose. **Bursting Strength Test.**

(*b*) *Lying Straight.*—In the lying straight position the sample shall be allowed to rest on the surface of the test table with one end free and the test pressure shall be applied in accordance with Section 53.

(*c*) *Curved.*—In the curved position the sample shall be secured at both ends to a suitable test frame which is curved to a radius of 27 in. The test pressure shall be applied in accordance with Section 53.

56. The test length in the kink test shall have a coupling tied back against the body of the hose so that there will be a sharp kink in the hose about 18 in. from the coupling. The test pressure shall be applied in accordance with Section 53. **Kink Test.**

TENTATIVE SPECIFICATIONS
FOR
RUBBER INSULATING TAPE[1]

Serial Designation: D 119 - 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and **suggestions,** and as such is subject to annual revision.

ISSUED, 1921; REVISED, 1922, 1927, 1928.

Scope. 1. These specifications cover rubber insulating tape to be used for insulating joints in electric wires and cables.

MANUFACTURE

Compound. 2. The tape shall be made from an unvulcanized rubber compound which shall be well, evenly and smoothly calendered, cut to uniform width and tightly wound in rolls with a glazed cloth, parchment paper or a linen separator interposed between adjacent layers.

Separator. 3. The separator shall be attached to and cover the outer side of the tape. When unwound from the original roll, it shall show no undue tendency to stick to the rubber.

CHEMICAL PROPERTIES AND TESTS

Composition. 4. The tape shall be a rubber compound containing not less than 30 per cent of the best quality Hevea rubber, not more than one per cent of free sulfur.

The remainder shall consist only of suitable dry inorganic mineral fillers. The compound shall contain no reclaimed rubber, substitutes or organic matter other than herein above specified. All percentages shall be based on the weight of the original compound.

Chemical Analysis. 5. If an analysis of the compound is made, it shall be carried out in accordance with (*B*) Complete Procedure as described in Sections 14 to 60 of the Tentative Methods of Chemical Analysis of Rubber

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. Arthur W. Carpenter, Secretary of Committee D-11 on Rubber Products, The B. F. Goodrich Co., Akron, Ohio.

Products (Serial Designation: D 297 – 28 T) of the American Society for Testing Materials,[1] with the following exceptions:

(*a*) Omit Paragraph (*b*) of Section 15.

(*b*) Omit Section 30.

(*c*) In Section 31 substitute "acetone" for "chloroform" in the first sentence.

(*d*) In Section 40 change the first paragraph to read as follows: "Extract a 0.5-g. sample for 8 hours with acetone." In the first sentence of the second paragraph substitute "acetone" for "chloroform."

(*e*) In the first sentence of Section 46 (*a*) substitute "acetone" for "a constant boiling mixture of acetone and chloroform."

(*f*) In Section 54 omit "chloroform extract."

(*g*) In Section 55 omit "chloroform extract."

(*h*) In Section 56 omit Paragraph (*c*) "Percentage of chloroform extract."

(*i*) In Section 60 (*b*) omit "chloroform."

PHYSICAL PROPERTIES AND TESTS

Tensile Strength.

6. (*a*) The tensile strength of the tape shall be not less than 250 lb. per sq. in.

(*b*) The tests shall preferably be made with a power driven, pendulum-type tension testing machine; the initial distance between the jaws shall be 3 in. and the rate of separation of the jaws shall be 20 in. per minute. The width of the test specimen shall be 0.5 in.

(*c*) Three specimens of each sample free from visible flaws shall be tested. The average result shall be taken as the tensile strength.

(*d*) The temperature of the room shall be not lower than 65° F. (18° C.) nor higher than 90° F. (32° C.) and the samples shall have been kept within these temperature limits for at least 30 minutes previous to the time of testing.

Dielectric Strength.

7. Two brass-ball sphere electrodes 2 cm. in diameter shall be brought so close together that the sample of tape can be just moved between them. The tape shall withstand without puncturing the application of a potential of 10,000 volts (r.m.s. value) for a period of five minutes applied to the sphere electrodes at a frequency not exceeding 65 cycles per second.

Fusion.

8. The tape shall be tested for fusion as follows:

(*a*) The sample shall have been kept at a room temperature of not less than 65° F. (18° C.) nor more than 90° F. (32° C.) for at least 30 minutes previous to making the test.

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[1] See p. 1072.

(*b*) The sample shall be tested on a mandrel $\frac{1}{4}$ in. in diameter which shall be mounted in a level position in ball bearings of the Fafnir Bearing Co., Catalog No. 0.096, or equivalent ball bearings. The mandrel shall turn freely under a weight of 5 g. suspended from a cotton thread wound in a single layer on the center of the mandrel. See Fig. 1 for recommended form of tape tester.[1]

(*c*) A sample 7 in. long shall be taken from the roll, care being taken not to touch the surface to be tested with the hands or otherwise, and 2 in. of the sample shall be wound on the mandrel, and then a weight of 4 lb. per inch of width of the tape shall be attached and the tape wound on the mandrel for 3 in. at the uniform rate of approximately 15 r.p.m. The tape shall stand for 3 minutes with the weight attached and then allowed to unwind at the same rate until the fused turns are reached. The tape shall then sustain the weight for 2 minutes without further unwinding or shall break at the point of unwinding.

FIG. 1.—Illustration of Tape Tester.

Test Samples. 9. One roll for each 250 rolls shall be taken at random for test. At least 2 ft. of the outer layers shall be removed and discarded before taking specimens for test.

STANDARD WEIGHTS, DIMENSIONS AND VARIATIONS

Thickness, Weight and Yardage. 10. The tape shall conform to the following requirements:

WIDTH, IN.	NOMINAL THICKNESS, IN.	NOMINAL WEIGHT PER ROLL, LB.	MINIMUM NET WEIGHT PER 100 ROLLS, LB.[a]	MINIMUM LENGTH PER POUND, YD.[b]
½	0.030	½	50	26¼
¾	0.030	½	50	17½
1	0.030	1	100	13

[a] Exclusive of core, wrapping and box.

[b] Exclusive of core, wrapping, box and separator.

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[1] A detailed drawing of the tape tester may be obtained from the Secretary of Committee D-11.

11. The width shall not vary from the specified value by more than $\frac{1}{32}$ in. The thickness shall not vary from the specified value by more than 0.003 in. **Permissible Variations.**

12. The thickness shall be measured with a micrometer graduated to 0.001 in. having a circular foot, 0.24 to 0.26 in. in diameter, and with a pressure on the specimen of not less than 8 oz. or more than 10 oz. Four measurements shall be made at random in a length of not less than 3 ft. and no measurement shall be outside the limits prescribed in Sections 10 and 11. **Measurement of Thickness.**

PACKING AND MARKING

13. Each roll shall be wrapped in paraffined paper or metal foil and enclosed in a suitable box. The wrapping shall be secure and shall thoroughly protect the contents. **Packing.**

14. Each box shall be marked with the name of the manufacturer or trade mark and the nominal width and weight of the tape. **Marking.**

INSPECTION AND REJECTION

15. The tape shall be tested and inspected within four weeks of the date of delivery. **Time of Inspection.**

16. If the tape fails in any one test of those prescribed in these specifications, two additional specimens shall be taken and submitted to that test. If either of these two additional specimens fails, the lot of tape represented by that sample roll shall be rejected. **Retest and Rejection.**

TENTATIVE METHODS OF CHEMICAL ANALYSIS
OF
RUBBER PRODUCTS[1]

Serial Designation: D 297 - 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1928.

(A) *Short Procedure*

GENERAL INSTRUCTIONS

Blanks. 1. Blank tests shall be run on all determinations and deductions made accordingly.

Checks. 2. In the event of any determination not falling within the limits given in these methods of test, a duplicate determination which shall agree within the limits specified shall be made and the average value taken as the true value.

Preparation of Specimen. 3. (*a*) A specimen weighing not less than 15 g. shall be prepared, taking pieces from various parts of the sample.

(*b*) The specimen shall be cut into small pieces and run through a grinder until all of it will pass through a No. 20 sieve.[2] Care must be taken that the grinder does not become appreciably warm. The backing shall be buffed off before grinding.

Removal of Iron and Care of Specimen. 4. A strong magnet shall be passed through the specimen to remove any metal from the grinder, and the specimen shall be mixed thoroughly and put in tightly stoppered bottles. It shall not be exposed to sunlight or heat.

REAGENTS

5. (*a*) *General Requirements.*—All reagents shall be of a purity equal to that called for in Krauch's "Standard Chemical Reagents, Their Purity and Use."

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[1] Criticisms of these Tentative Methods are solicited and should be directed to Mr. Arthur W. Carpenter, Secretary of Committee D-11 on Rubber Products, The B. F. Goodrich Co., Akron, Ohio.

These methods are essentially those adopted as standard by the American Chemical Society and the U. S. Bureau of Standards and include the Joint Rubber Insulation Committee's Procedure.

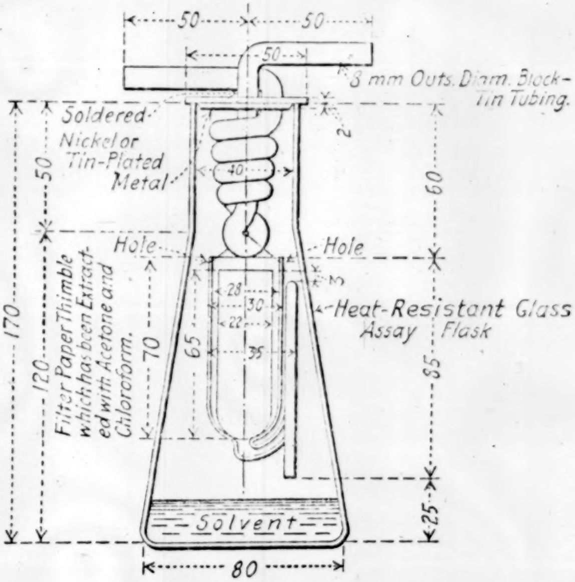
These methods will supersede, when adopted, the Chemical Tests appearing in Sections 1 to 47, inclusive, of the Standard Methods of Testing Rubber Products (Serial Designation: D 15 - 24), see 1927 Book of A.S.T.M. Standards, Part II, p. 847.

[2] For detailed specifications for this sieve, see the Standard Specifications for Sieves for Testing Purposes (Serial Designation: E 11) of the American Society for Testing Materials, 1927 Book of A.S.T.M Standards, Part II, p. 917.

(*b*) *Acetone.*—Acetone shall be distilled not more than 10 days before use over anhydrous potassium carbonate, using the fraction which distills at 56 to 57° C.

(*c*) *Alcoholic-Potash Solution.*—Alcoholic potash shall be of normal strength, made by dissolving the required amount of KOH in absolute alcohol the day before use, and allowing to settle. Only the clear solution shall be used.

(*d*) *Barium-Chloride Solution.*—Barium-chloride solution shall be made by dissolving 100 g. of crystallized barium chloride in one liter of distilled water and adding two or three drops of concentrated HCl. If there is any insoluble matter or cloudiness, the solution shall be heated over night on the steam bath and filtered.


50
50
50
8 mm Outs. Diam. Block-Tin Tubing.
Soldered Nickel or Tin-Plated Metal
2
40
50
60
Hole
Hole
170
120
Filter Paper Thimble which has been Extracted with Acetone and Chloroform.
70
65
28
30
22
35
3
Heat-Resistant Glass Assay Flask
85
25
Solvent
80

(All dimensions in millimeters.)

FIG. 1.—Extraction Apparatus.

METHODS OF ANALYSES

ACETONE EXTRACT

6. The extraction apparatus shall conform to that shown in Fig. 1. It shall be heated so that the period of filling an empty siphon cup with acetone and completely emptying it will be between 2½ and 3½ minutes. **Extraction Apparatus.**

Procedure.

7. Two grams of the rubber shall be extracted continuously with acetone for 8 hours, using a sample that has been prepared within 24 hours. Distill off the acetone and dry the flask and contents for 4 hours at 95 to 100° C. Desiccate until cool and weigh. Continue to dry for 2-hour periods until constant weight is obtained. In drying place the flask on its side but at a sufficient angle from the horizontal so that the extract does not appreciably run down from the side of the flask.

FREE SULFUR

Free Sulfur.

8. Add to the flask containing the acetone extract 50 to 60 cc. of distilled water and 2 or 3 cc. of bromine (if the acetone extract indicates a large amount of free sulfur, the amount of bromine should be increased). Heat gently on the steam bath until the solution is practically colorless and filter into a 400-cc. beaker. Dilute with distilled water until the volume is about 400 cc. Cover the beaker with a watch glass, heat to boiling on the steam bath, add 10 cc. of barium-chloride solution (10-per-cent) and allow the precipitate to stand over night. The next day filter off the precipitate, ignite the filter paper and weigh.

ALCOHOLIC-POTASH EXTRACT

Alcoholic-Potash Extract.

9. Dry the residue from the acetone extraction at 50 to 60° C., put into a 200-cc. Erlenmeyer flask with 50 cc. of the alcoholic KOH solution and boil for 4 hours under a reflux condenser. Filter the solution into a beaker and wash twice, using each time 25 cc. of hot absolute alcohol and then wash thoroughly with hot water. Evaporate the solution to approximate dryness, take up in warm water and transfer to a separatory funnel. Acidify with 15 cc. of 5 *N* HCl, using this to rinse the beaker. Add sufficient water to make the bulk of the solution 100 cc. When cool, add 40 cc. of ether, using it to rinse the beaker in 20-cc. portions. Shake the aqueous and ethereal solutions thoroughly. After complete separation, draw off the aqueous solution and treat in another separatory funnel, with a fresh 20-cc. portion of ether. Continue to shake the aqueous solution with fresh portions of ether until a colorless portion has been obtained, then shake out twice more. Unite the ethereal solutions and wash with successive additions of water, continuing twice after the water shows no acid reaction. Filter through a plug of extracted cotton into a tared flask, wash the filter and funnel with ether, evaporate the ether without boiling and dry the residue to constant weight at 95 to 100° C. Cool in a desiccator and weigh.

TOTAL SULFUR

10. Mix a 0.5-g. sample with 4 g. of Na_2O_2 and 6 g. of K_2CO_3 in a dry 15-cc. iron crucible. Cover and heat gradually until the mixture fuses, proceeding cautiously, as rapid heating will cause an explosion. Then bring to quiet fusion for 15 to 20 minutes, applying heat so as to avoid contamination with sulfur fumes. Rotate the crucible while the melt solidifies. When cool, put crucible and cover into a casserole containing 200 cc. of water; add 5 to 10 cc. of bromine water and boil until the melt is dissolved. Allow the precipitate to settle, decant the liquid through a thick filter and wash the residue with hot water. Acidify the filtrate with HCl, evaporate to dryness and dehydrate if silica is present; add 2 cc. of concentrated HCl, take up in water, filter and wash, making the total volume about 400 cc. Heat to boiling and add slowly a slight excess of hot barium-chloride solution (10-per-cent). Allow to stand over night, filter, wash, ignite, weigh the $BaSO_4$ and calculate to sulfur. **Total Sulfur.**

ASH

11. Weigh out a 1-g. sample in a porcelain crucible, heat in a muffle furnace, the temperature of which is carefully regulated so that no material amount of visible products are given off. After the mass is charred, the temperature shall be raised sufficiently to burn the carbon. The whole process shall be conducted at as low a temperature as possible. At the end of this operation the crucible shall be removed from the furnace, cooled in a desiccator and weighed; the ash broken up and inspected for carbon. If any visible carbon is present, a new determination shall be conducted. **Ash.**

CALCULATIONS

12. The percentage of rubber shall be considered to be the difference between 100 and the sum of the total sulfur and ash expressed as percentages and figured on the total compound. If the alcoholic-potash extract is over 2 per cent of the rubber as first calculated, subtract this excess also from the rubber. The organic-acetone extract shall be obtained by taking the difference between the total acetone extract and the free sulfur. The organic-acetone extract, free sulfur, total sulfur and alcoholic-potash extract shall be figured on the amount of gum as found by the above procedure. **Calculations.**

CHECK ANALYSES

13. Duplicate determinations when required shall check within **Check Analyses.**

the following limits, expressed as percentages of the gum present, as found by analysis, except as stated:

	CHECK WITHIN, PER CENT
Organic-acetone extract	0.10
Free sulfur	0.10
Total sulfur	0.10
Alcoholic-potash extract	0.10
Ash calculated on total compound	0.25

(*B*) *Complete Procedure*

Scope. 14. These methods cover the complete procedure of analysis of rubber products to determine whether they comply chemically with specifications which are intended to secure compounds containing 30 per cent of the best Hevea rubber, and mineral fillers. In addition, there is a method which employs a solvent for the vulcanized rubber. This method has proved to be more accurate than an ash determination when carbonates are present in a rubber compound and may also be used in the analysis of asbestos rubber packings and rubberized fabrics.

DEFINITIONS

Definitions. 15. (*a*) *Acetone Extract.*—If the acetone extraction is made on a vulcanized compound, the acetone removes the rubber resins, the free sulfur, any mineral oils or waxes, and part of any bituminous substances or vulcanized oils that may have been used. This is generally called acetone extract uncorrected. The percentage of free sulfur is determined and deducted from the total extract. The value obtained is known as acetone extract corrected. The corrected figure thus obtained will at times give valuable information regarding the quality of the rubber present. For the best grades of Hevea rubber this should not exceed 5 per cent of the rubber present. A higher extract may indicate the presence of inferior or reclaimed rubbers.

(*b*) *Chloroform Extract.*—The chloroform extraction removes a portion of the bituminous substances and serves as an indication of their presence.

(*c*) *Alcoholic-Potash Extract.*—The purpose of the alcoholic-potash extraction is to detect the presence of rubber substitutes.

(*d*) *Free Sulfur.*—Free sulfur is that which is removed during the acetone extraction.

(*e*) *Total Sulfur.*—Total sulfur is the sulfur that occurs in the compound, either free or chemically combined, unless barium sulfate is present, in which case the amount of sulfur in it is deducted from the amount of total sulfur.

(*f*) *Ash.*—The ash is the residue left after ignition and consists principally of the non-volatile mineral fillers, together with their reaction products with sulfur.

(*g*) *Sulfur in Ash.*—The sulfur in ash consists of the sulfur from the mineral fillers and also part of the sulfur that was with the rubber, but which during ignition enters into combination with mineral fillers.

(*h*) *Total Compounding Ingredients.*—Total compounding ingredients consist of the residue obtained when the rubber is dissolved by mineral oil in the solution method of analysis. Total compounding ingredients corrected is the value obtained after deducting sulfur and organic matter present.

Special Determinations.

16. Special methods are given for the analysis of compounds that contain glue, carbon, antimony, and waxy hydrocarbons.

Indirect Methods.

17. (*a*) Up to the present time, no simple method has been devised for the direct determination of the amount of rubber present in a vulcanized compound. Therefore, an indirect method is proposed which will give satisfactory results in all cases known today, except where there are found to be present decomposible compounding ingredients, such as carbonates, cellulose, and high percentages of mineral rubbers. As practically all insulating compounds contain some of these ingredients, the said compounds when specified shall be analyzed in accordance with the Joint Rubber Insulation Committee's Procedure as described in Section 45.

(*b*) When carbonates, talc, and asbestine are present more accurate results are obtained by the use of the Joint Rubber Insulation Committee's Procedure described in Section 45, or by the Rubber Solvent Method described in Sections 57 to 60, inclusive.

(*c*) If high percentages of mineral rubber are used, no accurate method is known. If cellulose is present the best results are obtained by the method described in Section 46.

REAGENTS

Reagents.

18. (*a*) *Acetone.*—The acetone shall be chemically pure and shall be freshly redistilled over anhydrous sodium carbonate, using the 56 to 57° C. fraction.

(*b*) *Alcoholic-Potash Solution.*—The alcoholic-potash solution shall be of normal strength. It shall be made by dissolving the required amount of KOH in alcohol which has been purified as follows:

Dissolve 1.5 g. of $AgNO_3$ in 3 cc. of water and add it to 1000 cc. of alcohol. Dissolve 3 g. of KOH in the smallest amount of hot water, cool, add it to the alcoholic-silver nitrate solution, and shake thoroughly. Allow the solution to stand for at least 24 hours, filter, and distill. (Alcohol denatured with 10 per cent by volume of methanol may be used in place of ethyl alcohol.)

(*c*) *Nitric Acid-Bromine Solution.*—The nitric acid-bromine solution shall be prepared by adding a considerable excess of bromine to concentrated HNO_3 and shaking thoroughly.

(*d*) *Zinc-Nitric Acid Solution.*— The zinc-nitric acid solution is made by adding 200 g. of zinc oxide to 1000 cc. of concentrated HNO_3.

(*e*) *Barium-Chloride Solution.*—Barium-chloride solution shall be made by dissolving 100 g. of crystallized barium chloride in 1 liter of distilled water, and adding two to three drops of concentrated HCl. If there is any insoluble matter or cloudiness, the solution shall be heated overnight on the steam bath and filtered.

(*f*) *Standard 0.1 N Potassium Permanganate Solution.*—Dissolve approximately 3.1 g. of potassium permanganate in 1 liter of water, and after about one month filter through an ignited asbestos pad. Weigh 0.25 g. of pure metallic antimony and transfer it to a 600-cc. Erlenmeyer flask. Add 12 to 15 cc. of concentrated H_2SO_4, 10 to 12 g. of potassium sulfate, and heat until all the antimony is dissolved. Dilute to 250 cc. with water, add 20 cc. of concentrated HCl, cool to 10 to 15° C., and titrate with permanganate solution until a faint pink color is obtained.

$$1 \text{ cc. of } 0.1\ N\ KMnO_4 = \frac{\text{Wt. of metallic antimony}}{\text{cubic centimeters of permanganate}}$$

(*g*) *Starch Iodate Paper.*—Starch iodate paper is prepared by impregnating filter paper with a solution obtained by heating 2 g. of starch with 100 cc. of water and, after solution, adding 0.2 g. of potassium iodate dissolved in 5 cc. of water.

(*h*) *Rubber Solvent.*—The mineral oil used in the solution method of determining rubber and fillers shall have approximately the following properties: Vicosity at 68° F., 56 seconds; at 100° F., 45 seconds; flash point 270° F.; fire point 350° F.; and specific gravity 0.853, and shall be colorless.

(*i*) *Asbestos Gooch Crucible.*—Prepare a Gooch crucible in the following manner: Amphibole asbestos is cut fine with shears, digested with caustic-soda solution (10-per-cent), washed with water, and then digested with concentrated HCl for a few hours on the steam bath. After it has been washed comparatively free from acid by decantation, the asbestos is shaken up with water and the resulting mixture is used in preparing the pad. The Gooch crucible is ignited, and is then ready for use.

BLANK ANALYSES

Blank Analyses.

19. The purity of all materials shall be checked and determined by blank analyses.

PREPARATION OF SAMPLES

Preparation of Samples.

20. (*a*) Before preparing a sample for analysis the analyst shall, by inspection, assure himself that it has not been contaminated. The sample shall be prepared by taking pieces from various parts of the original sample and separating them from foreign matter. The rubber shall be ground to the required fineness on a rubber mill or cut with scissors so as to pass a No. 14 sieve. Hard rubber should be prepared by rasping with a coarse file, cleaning with a magnet, and passing through a No. 14 sieve.

(*b*) Crude, reclaimed, or unvulcanized rubber shall be sheeted out very thin on an experimental mill and shall be rolled in holland or other cotton cloth to prevent the sample from sticking. If no mill is available, the sample shall be cut with scissors as fine as possible.

(*c*) Samples of rubberized cloth shall be prepared by cutting into pieces, 1.5 mm. square, and then mixing well.

(*d*) *Cements.*—Evaporate to dryness in a vacuum and analyze the residue as an unvulcanized sample. Distill a separate sample under reduced pressure if examination of the solvent is desired.

PRELIMINARY EXAMINATION OF SAMPLE

Carbonates.

21. Drop a small piece of the sample into a test tube containing concentrated HCl saturated with bromine. If a stream of bubbles is given off, the Rubber Solvent Method described in Sections 57 to 60, inclusive, shall be used.

Antimony.

22. Place a portion of the sample in a porcelain crucible and burn off the rubber. Treat the ash with concentrated HCl. Dilute the solution to 10 times its volume, filter and saturate with H_2S. If a precipitate of antimony sulfide is formed, the method described in Section 38 or the Rubber Solvent Method in Sections 57 to 60, inclusive, should be used.

Carbon Black.

23. Heat a portion of the sample with concentrated HNO_3 until there is no more frothing. If the liquid is black, it indicates the presence of free carbon, and the test for this substance should be made.

Barium Salts.

24. A qualitative test for barium can conveniently be made on the residue after filtration in the total sulfur determination as described in Section 33, by dissolving it in HCl (10-per-cent), filtering and then adding a few drops of H_2SO_4 (10-per-cent). A white pre-

cipitate of barium sulfate indicates the presence of barium in the sample.

Paraffin. 25. If paraffin is present, it will solidify in the cold acetone extract as a white flucculent precipitate clinging to the sides of the flask.

Glue. 26. Extract a portion of the sample with a mixture of 32 per cent acetone and 68 per cent chloroform by volume for 8 hours. Dry the sample and digest for 1 hour with hot water. Filter, cool, and add a few drops of a freshly prepared solution of tannic acid (2-per-cent) and allow to stand for a few minutes. If the solution becomes turbid, glue is present and should be determined as described in Section 41.

METHODS OF ANALYSES

SPECIFIC GRAVITY

Specific Gravity. 27. Specific gravity shall be determined by the use of a pycnometer, using alcohol in place of water, to eliminate the errors due to air bubbles:

$$\text{Sp. gr.} = \frac{C}{C - (B - A)} \times \text{sp. gr. of alcohol}$$

where A = weight of the pycnometer filled with alcohol;
B = weight of the pycnometer filled with sample and alcohol,
C = weight of the sample.

ACETONE EXTRACT

Extraction Apparatus. 28. The extraction apparatus used here and for other extractions shall be of the type shown in Fig. 1. The flask shall be heated so that the period of filling an empty siphon cup with acetone and completely emptying it will be between 2.5 and 3.5 minutes.

Procedure. 29. Place 2 g. of rubber in a thimble made by folding a filter paper so that it will fit in the extraction cup, which is suspended in a weighed extraction flask. Extract the sample continuously for 8 hours, unless the solution in the thimble is still colored at the end of that time, when the extraction shall proceed for a further period of 4 hours or longer. For hard rubber the extraction period shall be a minimum of 72 hours. Carefully note all characteristics of the acetone extract, both when hot and cold. Distill off the acetone on a steam bath, recovering the acetone if desirable, at as low a temperature as possible. Loss of extract by bumping can be avoided by means of a gentle current of air. Care must be taken to avoid allowing the flasks to stand on the steam bath after the solvent has been removed, because appreciable quantities of free sulfur may be lost by so doing. Dry the extraction flask and contents in an air bath for 1 hour at 70° C., cool, and weigh. Call the residue "acetone extract, uncorrected." Keep the sample for future determinations.

$$\text{Percentage of acetone extract, uncorrected} = \frac{\text{Wt. of extract}}{\text{Wt. of sample}} \times 100$$

CHLOROFORM EXTRACT

Chloroform Extract.

30. The rubber sample (see Sections 28 and 29) is suspended in a second weighed extraction flask and extracted for 4 hours with chloroform. Care should be taken that any small particles of rubber, which are often carried down into the extract, are filtered off. Evaporate off the solvent and dry to constant weight, usually 1 hour at 70° C., cool, and weigh. The color of the chloroform solution should be recorded. Reserve the rubber for extraction with alcoholic potash.

$$\text{Percentage of chloroform extract} = \frac{\text{Wt. of extract}}{\text{Wt. of sample}} \times 100$$

ALCOHOLIC-POTASH EXTRACT

Alcoholic-Potash Extract.

31. Dry the rubber from the chloroform extraction at about 70° C. to remove the chloroform, transfer to a 200-cc. Erlenmeyer flask, add 50 cc. of alcoholic-potash solution, and heat under a reflux condenser for 4 hours. Filter into a 250-cc. beaker, wash with two portions of 25-cc. of boiling alcohol; then with three 25-cc. portions of boiling water, and evaporate the filtrate to dryness. Use about 75 cc. of distilled water to transfer the residue to a separatory funnel. Acidify the solution with HCl (10-per-cent), testing with Congo red paper. Extract with four 25-cc. portions of ether, unless the fourth portion should be colored, when the extraction must be continued until no further quantity can be removed. Unite the ether fractions and wash thoroughly with distilled water until free from acid (two washings are generally sufficient). Filter the ether solution through a plug of absorbent cotton into a weighed flask, wash with ether, evaporate, dry to constant weight at 70° C., cool, and weigh.

$$\text{Percentage of alcoholic-potash extract} = \frac{\text{Wt. of extract}}{\text{Wt. of sample}} \times 100$$

FREE SULFUR

Free Sulfur.

32. Add to the flask containing the acetone extract, uncorrected (Sections 28 and 29), 60 cc. of distilled water and 2 to 3 cc. of bromine,

and cover with a watch glass. Allow the flask to stand 30 minutes on the side of the steam bath, then heat cautiously over the direct steam bath until the solution is practically colorless, filter into a 250-cc. beaker, and dilute to about 175 cc. with distilled water. Precipitate with barium chloride and determine in the usual manner.

$$\text{Percentage of free sulfur} = \frac{\text{Wt. of BaSO}_4 \times 0.1373}{\text{Wt. of sample}} \times 100$$

TOTAL SULFUR

Total Sulfur, Recommended Method.

33. Place 0.5 g. of rubber in a porcelain crucible of about 75-cc. capacity, add 15 cc. of the nitric acid-bromine mixture, cover the crucible with a watch glass, and let it stand for 1 hour in the cold. Heat for 1 hour on the steam bath, remove the cover, rinse it with a little distilled water, and evaporate to dryness. Add 3 cc. of HNO_3, cover, warm a short time on the steam bath, then let it cool. Carefully add in small portions, by means of a glass spatula, 5 g. of sodium carbonate (weighed to 0.5 g.). The watch glass is to be raised only high enough to permit the introduction of the spatula. The carbonate is allowed to slide down the side of the crucible and is not dropped directly into the acid. Rinse the watch glass with 2 or 3 cc. of hot distilled water and stir the mixture thoroughly with a glass rod. Digest for a few minutes, spread the mixture halfway up the side of the crucible to facilitate drying, and dry on a steam bath. Fuse the mixture by heating over a sulfur-free gasoline flame.

Place the crucible in an inclined position on a wire triangle and start the ignition over a low flame. The tendency for the organic matter to burn too briskly is controlled by judicious use of the stirring rod with which the burning portion is scraped away from the rest. When part of the mass is burned white, a fresh portion is worked into it until all of the organic matter is destroyed. It is necessary to hold the edge of the crucible with tongs. Toward the last half of the operation the flame should be increased. It is unnecessary to heat the crucible to redness. With care, a crucible can be used for at least 10 to 12 fusions.

After a fusion, allow the crucible to cool, place it in a 400-cc. beaker, add sufficient distilled water to cover the crucible (about 125 cc.), and digest on the steam bath for 2 hours, with occasional stirring. If the filtration can not be made on the same day, do not add the water, but allow the fusion to stand overnight.

Filter the solution into a covered 400-cc. beaker containing 5 cc. of concentrated HCl, and wash the residue thoroughly with hot water. (A qualitative test for barium can be made on the residue.) Complete the acidification of the filtrate and washings and add 2 cc. of concentrated HCl in excess. Cover the beaker and heat the solution on the steam bath. The total volume of the solution should be 300 cc. The solution must be acid to Congo paper in order to insure the complete destruction of the carbonates. Precipitate with barium chloride and determine the sulfur in the usual manner.

$$\text{Percentage of total sulfur} = \frac{\text{Wt. of } BaSO_4 \times 0.1373}{\text{Wt. of sample}} \times 100$$

Total Sulfur, Alternate Method.

34. *Alternate Method.*—When this method is used the total sulfur determined represents the sulfur exclusive of that originally present as barytes or formed from barium salts, if present in the compound.

Place a 0.5-g. sample in a 500-cc. Erlenmeyer destruction flask (Pyrex glass). Add 10 cc. of zinc oxide - nitric acid solution and moisten the sample thoroughly. If convenient, the mixture may be allowed to stand overnight. By so doing the sample becomes partly decomposed; this permits the addition of fuming HNO_3 with no danger of ignition of the sample. Add 15 cc. of fuming HNO_3 and whirl the flask rapidly to keep the sample immersed to avoid ignition by too rapid oxidation. With some samples it will be found necessary to cool the flask under a stream of tap water.

When the solution of the rubber is complete, add 5 cc. of a saturated water solution of bromine and slowly evaporate the mixture to a foamy sirup. (For the determination of total sulfur in unvulcanized mixtures use 3 cc. of bromine in place of bromine water.)

If particles of organic matter remain at the end of the evaporation, add a few cubic centimeters of fuming HNO_3 and re-evaporate as before. Cool, and add a few crystals of potassium chlorate to assist in the oxidation of the sulfur and the decomposition of any nitrates.

Place the flask on asbestos gauze and evaporate the mixture to dryness over a Tirrill burner. Then bake the mixture at the highest temperature of the burner until all nitrates are decomposed and no more nitrogen peroxide fumes can be detected. When the baking is complete, cool the flask, add 50 cc. of HCl (1:6) and heat until solution is complete. (In case the original mixture contains barium sulfate or other barium salts, they will be precipitated at this point with consequent loss of sulfur in the case of the latter. If litharge is present in the mixture, lead salts, not otherwise removed, will be eliminated in the final washing with boiling water.) Filter the solution, dilute to 300 cc., precipitate with barium chloride, and determine the sulfur in the usual manner.

$$\text{Percentage of total sulfur} = \frac{\text{Wt. of } BaSO_4 \times 0.1373}{\text{Wt. of sample}} \times 100$$

ASH

Ash.

35. Wrap a 1-g. sample in a filter paper, extract with acetone for 4 hours, and transfer to a weighed, approximately 50-cc. porcelain crucible. Ash the sample in a muffle furnace by heating at the following rate:

Time, minutes	0	5	10	15	70	75	80	85	145
Temperature, deg. Centigrade	0	100	200	300	300	400	500	550	550

Remove the crucible from the furnace, cool, and weigh.

$$\text{Percentage of ash} = \frac{\text{Wt. of ash}}{\text{Wt. of sample}} \times 100$$

If no furnace is available, distill off the rubber over a very small flame, not allowing it to catch fire, and ignite gently until burnt clean, cool, weigh, and determine ash in the usual manner.

SULFUR IN ASH

Sulfur in Ash.

36. Add 3 cc. of nitric acid - bromine mixture to the ash (see Section 35), cover with a watch glass and heat for 1 hour, remove the cover, rinse it with a little distilled water, and evaporate to dryness. Complete the determination of sulfur as described in Section 33.

Save the insoluble residue, after filtering the solution of the fusion mixture in water, for testing in accordance with Section 37.

SULFUR AS BARIUM SULFATE

Sulfur as Barium Sulfate.

37. The barium sulfate is calculated from the barium in the ash, which is determined as follows: Filter off the insoluble matter after the fusion and extraction described in Section 36, wash back into the original beaker with hot water, dissolve the residue in the beaker and any traces on the filter paper with HCl, and heat the solution on the steam bath. Filter through the same filter as before and wash thoroughly with hot water. Nearly neutralize the solution with NH_4OH, leaving it slightly acid. Saturate the cold solution with H_2S, and when the lead sulfide has settled, filter into a 400-cc. beaker and wash thoroughly. The total volume should be not over 200 cc. Precipitate with H_2SO_4 (10-per-cent) and determine the sulfur in the

usual manner. Barium sulfate determined above is assumed to have been added as such. Obviously, if barium carbonate is present, it must be determined in order that an undue correction will not be made.

$$\text{Percentage of sulfur as barium sulfate} = \frac{\text{Wt. of BaSO}_4 \times 0.1373}{\text{Wt. of sample}} \times 100$$

TOTAL ANTIMONY

Total Antimony.

38. When a qualitative test indicates that antimony is present, weigh out a 0.5-g. sample, and transfer to a Kjeldahl flask, add 25 cc. of concentrated H_2SO_4 and 10 to 12 g. of potassium sulfate, place a funnel in the neck of the flask, and heat until the solution becomes colorless. Cool and wash the funnel, dilute the solution to 100 cc. with water, and transfer to a 400-cc. beaker, dilute to 250 cc. with hot water, and precipitate the antimony with H_2S. Filter and transfer the precipitate to a Kjeldahl flask, add 15 cc. of concentrated H_2SO_4, 10 to 12 g. of potassium sulfate, and heat as described above until the solution is colorless. Wash the funnel, dilute the solution to 100 cc. with water, add 1 to 2 g. of sodium sulfite, and boil until all the sulfur dioxide is driven out.

This is shown when no blue color is obtained with starch iodate paper. Add 20 cc. of concentrated HCl, dilute to 250 to 275 cc. with water, cool to 10 to 15° C., and titrate with standard 0.1 *N* permanganate solution until a faint pink color is obtained. If iron is found to be absent it is not necessary to precipitate the antimony with H_2S and the second heating in a Kjeldahl flask may be eliminated.

$$\text{Percentage of antimony} = \frac{\text{Sb (see Section 18 } (f)) \times \text{cubic centimeters of permanganate}}{\text{Wt. of sample}} \times 100$$

ANTIMONY IN THE ASH

Antimony in the Ash.

39. Antimony in the ash is determined on the ash of a 1-g. sample as follows: Transfer the ash to a 600-cc. Erlenmeyer flask, add 12 to 15 cc. of concentrated H_2SO_4 and 10 to 12 g. of potassium sulfate, and boil until solution is complete. It may be necessary to warm part of the H_2SO_4 in the crucible to transfer any adhering particles to the flask. Rinse with the remaining portion of acid. Then complete the determination as described in Section 38.

$$\text{Percentage of antimony as Sb}_2\text{O}_4 \text{ in ash} = \frac{\text{Sb (see Section 18 } (f)) \times \text{cubic centimeters of permanganate} \times 1.26}{\text{Wt. of sample}} \times 100$$

FREE CARBON

Free Carbon.

40. Extract a 0.5-g. sample for 8 hours with a mixture of 68 per cent chloroform and 32 per cent acetone by volume.

Transfer the sample to a 250-cc. beaker and heat on the steam bath until it no longer smells of chloroform. Add a few cubic centimeters of concentrated HNO_3 and allow to stand for about 10 minutes. Add 50 cc. more of concentrated HNO_3, taking care to wash down the sides of the beaker, and heat on the steam bath for at least 1 hour. At the end of this time there should be no more bubbles or foam on the surface. Pour the liquid while hot into a Gooch crucible, taking care to keep as much as possible of the insoluble material in the beaker. Filter slowly with gentle suction and wash well by decantation with hot concentrated HNO_3. Wash with acetone and a mixture of equal parts of acetone and chloroform until the filtrate is colorless. Digest the insoluble material, which has been carefully retained in the beaker, for 30 minutes on the steam bath with 35 cc. of sodium hydroxide solution (25-per-cent). This treatment with alkali may be omitted if silicates are absent. Dilute to 60 cc. with hot distilled water and heat on the steam bath. Filter the solution of alkali and wash well with hot sodium hydroxide solution (15-per-cent).

Next, wash the residue about four times with hot concentrated HCl. Neutralize the last washing with NH_4OH and test for the presence of lead with sodium chromate solution. If lead is present continue to wash with hot concentrated HCl and, finally, wash with warm HCl (5-per-cent). Remove the crucible from the funnel, taking care that the outside is perfectly clean, dry it in an air bath for $1\frac{1}{2}$ hours at 110° C., cool, weigh, burn off the carbon at a dull red heat, and reweigh. The difference in weight represents approximately 105 per cent of the carbon originally present in the form of lampblack or gas black.

$$\text{Percentage of free carbon} = \frac{\text{Wt. of crucible with carbon} - \text{wt. of crucible after ignition}}{1.05 \times \text{Wt. of sample}} \times 100$$

NITROGEN CALCULATED AS GLUE

Nitrogen Calculated as Glue.

41. When glue is found to be present, a correction must be made for the natural protein in the rubber. The average amount of nitrogen is 0.4 per cent. See Section 49 for calculations.

Extract a 2-g. sample for 8 hours with acetone. Remove the solvent from the sample, and transfer the latter from the filter paper to a 750-cc. Kjeldahl flask. Add 25 to 30 cc. of concentrated H_2SO_4, 10 to 12 g. of sodium sulfate, and about 1 g. of copper sulfate. Heat gently until the first vigorous frothing ceases, then raise the heat gradually until the liquid boils. Continue the boiling until the solution becomes clear. Allow the flask to cool, dilute carefully with 150 cc. of water, and again allow to cool. Add 100 cc. of sodium hydroxide solution (50-per-cent), pouring it carefully down the side of the flask, so that it does not mix immediately with the acid solution. Add about 1 g. of granulated zinc to prevent bumping and a piece of paraffin the size of a pea to diminish frothing. Connect the flask quickly with a condenser, the delivery tube of which dips into a 500-cc. Erlenmeyer flask, containing 50-cc. of 0.1 *N* H_2SO_4 diluted to about 100 cc. Carefully swirl the flask to mix the contents and start to heat gently, increase the flame as the danger of foaming over diminishes, and finally boil briskly until about one-half of the liquid has passed over into the receiver. Add methyl red solution and titrate the excess acid by means of 0.1 *N* NaOH solution. A blank determination should be made.

$$\text{Percentage of nitrogen as glue} = \frac{100\ (H_2SO_4 \times \text{normality} - \text{NaOH} \times \text{normality})\ (0.014)\ (6.5)}{\text{Wt. of sample}}$$

When a 2-g. sample is used this formula becomes:

$$\text{Percentage of nitrogen as glue} = (H_2SO_4 \times \text{normality} - \text{NaOH} \times \text{normality}) \times 4.55$$

UNSAPONIFIABLE MATTER

Unsaponifiable Matter.

42. If this determination is made the free sulfur shall be determined on a separate 2-g. sample.

Add to the acetone extract obtained from two 2-g. samples (see Section 29), 50 cc. of *N* alcoholic-potash solution, heat on the steam bath under a reflux condenser for 2 hours, remove the condenser and evaporate to dryness. Transfer to a separatory funnel, using about 100 cc. of water, add 25 cc. of ether, and shake. Allow the two layers to separate thoroughly, then draw off the water layer. Continue the extraction of the water layer with fresh portions of ether until no more unsaponifiable matter is removed, unite the ether layers, and wash with distilled water. Transfer the ether to a weighed flask, distill off the ether, dry to constant weight at 70° C., cool, and weigh.

$$\text{Percentage of unsaponifiable matter} = \frac{\text{Wt. of extract}}{\text{Wt. of sample}} \times 100$$

HYDROCARBONS *A*

Hydrocarbons A.

43. To the unsaponifiable matter (see Section 42), add 50 cc. of absolute alcohol, and heat on the steam bath for 30 minutes. Let the flask stand in a mixture of ice and salt for 1 hour. Filter off the separated waxy hydrocarbons on filter paper, by applying a gentle suction. Wash with alcohol (95-per-cent) which has been cooled in an ice-salt mixture. The funnel should be surrounded by a freezing mixture.

Dissolve the precipitate from the filter paper with hot chloroform, and catch the solution in a weighed 100 to 150-cc. beaker. Wash the flask with hot chloroform which is added to the same beaker, in order to include any insoluble matter adhering to the walls of the flask. Evaporate off the solvent, dry to constant weight at 70° C., cool, and weigh.

$$\text{Percentage of hydrocarbons } A = \frac{\text{Wt. of extract}}{\text{Wt. of sample}} \times 100$$

HYDROCARBONS *B*

Hydrocarbons B.

44. Evaporate the alcohol from the flask containing the alcohol soluble unsaponifiable material, add 25 cc. of carbon tetrachloride, and transfer to a separatory funnel. Shake with concentrated H_2SO_4, drain off the discolored acid, and repeat with fresh portions of acid until there is no longer any discoloration. After drawing off all the acid, wash the carbon tetrachloride solution with repeated portions of water until all traces of acid are removed. Transfer the carbon tetrachloride solution to a weighed flask, evaporate off the solvent, and dry to constant weight at 70° C., cool, and weigh.

$$\text{Percentage of hydrocarbons } B = \frac{\text{Wt. of extract}}{\text{Wt. of sample}} \times 100$$

RUBBER HYDROCARBONS

(JOINT RUBBER INSULATION COMMITTEE)

Joint Rubber Insulation Committee Procedure.

45. Add to the flask containing the rubber residue from the alcoholic-potash extraction sufficient water to make the total 125 cc. and then add 25 cc. of concentrated HCl. Heat for 1 hour at 100° C. Decant the supernatant liquid through a hardened filter paper on a Büchner funnel, 7 cm. in diameter, using suction. Wash the residue with 25 cc. of hot water and decant. (Although a Büchner funnel is recommended, it is permissible to use an 11-cm. hardened filter paper with platinum cone in a 60-deg. funnel.) Perform this entire

treatment with water and HCl three times. The rubber at this stage should be white and practically free from black specks of undissolved fillers; if not, continue the acid treatment until the black specks disappear. (If carbon is present, all the particles of rubber will be grayish, bluish, or black, depending on the form and quantity of carbon used. Black specks in light particles of rubber usually indicate the presence of lead sulfide which must be removed to prevent the formation of lead sulfate on igniting the residue *C*.) Add 150 cc. of hot water to the flask and allow to stand on a steam bath or hot plate for 30 minutes and decant through the filter paper, repeating until washings are free from chlorides. Transfer all the rubber in the flask to the filter paper and dry as much as possible by suction. Wash the rubber with 50 cc. of alcohol (95-per-cent), using suction. Transfer the entire residue to a weighing bottle. Dry at 95 to 100° C. for 1 hour, cool in a vacuum desiccator under reduced pressure and weigh. Dry for 30 minutes, cool, and weigh, repeating this process until either constant weight is reached or the weight starts to increase. Let this weight be represented by *C*. The weight originally taken for the acetone extract determination shall be called *A*. Determine the ash (*E*) on a portion (*D*) of this residue (*C*), and sulfur (*H*) on the remaining portion (*G*). Also determine the sulfur (*F*) on the ash (*E*). Perform the ash determination as described in Section 35, and the sulfur determination as described in Section 33.

$$\text{Percentage of rubber hydrocarbons} = 100\,\frac{C}{A}\left(1-\frac{H}{G}-\frac{E-F}{D}\right)$$

CELLULOSE

46. (*a*) Treat 0.5 g. of rubber previously extracted with a constant boiling mixture of acetone and chloroform with 25 cc. of rubber solvent oil (see Section 18 (*h*)), in a 250-cc. lipped assay flask. Place in an air bath at a temperature of 145 to 150° C. until small particles can be seen distinctly in the supernatant liquid, which requires about 3 hours. Dilute with 15 cc. of benzene and 200 cc. of petroleum ether. Filter through a Gooch crucible and wash the residue thoroughly with warm acetone. Treat repeatedly with hot HCl (10-per-cent) until the residue is free from acid-soluble fillers. Wash the pad well with boiling water, and run small portions of acetone through it until the filtrate is colorless. Wash with alcohol and dry at 105° C. to constant weight. Remove the pad from the crucible with the help of a pair of sharp-pointed tweezers, using the under portion of the pad as a swab to clean the sides of the crucible, and place all of this

Cellulose.

material in a tared weighing bottle. Replace in the drying oven for about 10 minutes, cool and weigh.

Weight of weighing bottle, pad, insoluble fillers, and cellulose minus weight of the weighing bottle equals weight of pad, insoluble fillers, and cellulose.

(*b*) Transfer the contents of the weighing bottle to a 50-cc. beaker and pour over it 15 cc. of acetic anhydride and 0.5 cc. of concentrated HS_2O_4, and allow to digest for at least 1 hour, on the steam bath. After the mixture has cooled thoroughly, dilute with 25 cc. of acetic acid (90-per-cent), and filter through a weighed Gooch crucible. To guard against traces of the material being carried through, this filtration, as well as the ones to follow, must be very slow and only gentle suction can be used. Wash with hot acetic acid (90-per-cent), until the filtrate comes through absolutely colorless and then wash about four times more. Wash with acetone about five times. After having taken care that all of the material has been washed out of the beaker in which the acetylation took place, remove the crucible from the funnel, clean the outside thoroughly, and dry for 2 hours at 150° C. Cool and weigh. The original weight of the crucible plus weight of pad, fillers, and cellulose minus the weight of the crucible after acetylation equals cellulose.

$$\text{Percentage of cellulose} = \frac{\text{Cellulose}}{\text{Wt. of sample}} \times 100$$

BARIUM CARBONATE

Barium Carbonate.

47. Bartyes was determined by the calculation to barytes of all barium found in the sample. Obviously, if barium carbonate is present, it must be determined in order that an undue correction will not be made. The determination is as follows: A 1-g. sample, in a porcelain boat, is placed in a combustion tube through which passes a current of carbon dioxide. The sample is ashed in the tube. After ignition and cooling, in the atmosphere of carbon dioxide, the boat is removed, the residue finely ground in an agate mortar, transferred to a 250-cc. beaker, and treated with 5 to 10 g. of ammonium carbonate, 15 to 20 cc. of strong ammonia water, and about 50 cc. of distilled water. The mixture is boiled for 20 minutes, filtered, and the precipitate thoroughly washed to remove all soluble sulfates. The residue on the filter paper is washed back into the original beaker and about 10 cc. of glacial acetic acid with sufficient water to make the total volume about 100 cc. is added. This is heated to boiling and filtered through the same paper as before. Hydrogen sulfide is passed into

the filtrate to precipitate the lead and the solution is subsequently treated as in the determination of barytes. The final weight of barium sulfate obtained is calculated to barium carbonate.

$$\begin{array}{c}\text{Percentage of sulfur required to convert}\\ \text{barium present as carbonate to sulfate}\end{array} = \frac{\text{Wt. of } BaSO_4 \times 0.1373}{\text{Wt. of sample}} \times 100$$

The Rubber Solvent Method described in Sections 57 to 60, inclusive, has been found to be more rapid in the determination of barium carbonate, and as accurate as the above method.

CALCULATIONS

Acetone Extract. 48. Percentage of acetone extract corrected, equals percentage of acetone extract, uncorrected, minus percentage of free sulfur, and percentage of waxy hydrocarbons. The percentage of waxy hydrocarbons equals percentage of hydrocarbons *A* plus percentage of hydrocarbons *B*.

Glue. 49. Multiply the percentage of rubber as compounded by 0.004 and 6.5 and call this value *A*. Subtract *A* from the percentage of glue and call this value *B*. Substitute *B* for glue in calculating the percentage of rubber hydrocarbons and then complete the calculations.

Sulfur as Antimony Trisulfide. 50. Percentage of sulfur as antimony trisulfide equals percentage of total antimony multiplied by $\frac{S_3}{Sb_2}$ equals percentage of total antimony multiplied by 0.400.

Antimony as Trisulfide. 51. Percentage of total antimony as trisulfide equals percentage of total antimony multiplied by $\frac{Sb_2S_3}{Sb_2}$ equals percentage of total antimony multiplied by 1.400.

Total Sulfur, Corrected. 52. Percentage of total sulfur corrected equals percentage of total sulfur minus percentage of sulfur as barium sulfate minus percentage of sulfur as antimony trisulfide. When barium carbonate is found, the percentage of sulfur necessary to convert it to sulfate must be added to the total sulfur, corrected.

Ash Corrected. 53. Percentage of ash corrected equals percentage of ash minus percentage of sulfur in ash plus percentage of sulfur as barium sulfate minus percentage of antimony in ash, calculated to Sb_2O_4.

Rubber Hydrocarbon. 54. Percentage of rubber hydrocarbon equals 100 minus the sum of the following percentages, except when it is determined by the Joint Rubber Insulation Committee's Procedure:

Acetone extract, corrected.
Chloroform extract.
Alcoholic-potash extract.
Total sulfur, corrected.
Ash, corrected.
Carbon.
Glue.
Total antimony as trisulfide.

Rubber as Compounded.

55. The percentage of rubber hydrocarbon plus 5 per cent of its weight is taken as "rubber as compounded," except when the sum of the percentages of the acetone extract corrected, chloroform extract, and alcoholic-potash extract is less than the figure represented by the arbitrary 5 per cent, as in many high-grade compounds. Percentage of rubber as compounded is then equal to the percentage of rubber hydrocarbon plus the sum of the percentages of the acetone extract corrected, the chloroform extract, and the alcoholic-potash extract.

$$\text{Percentage of rubber by volume} = \frac{\text{Percentage of rubber as compounded} \times \text{sp. gr. of compound}}{\text{0.94 (taken as the average sp. gr. of crude rubber)}}$$

$$\text{Ratio of acetone extract corrected} = \frac{\text{Percentage of acetone extract corrected}}{\text{Percentage of rubber as compounded}} \times 100$$

$$\text{Ratio of sulfur to rubber} = \frac{\text{Percentage of total sulfur, corrected}}{\text{Percentage of rubber as compounded}} \times 100$$

REPORT

Report.

56. The report shall include the following:

(*a*) Percentage of acetone extract, corrected;
(*b*) Percentage of waxy hydrocarbons;
(*c*) Percentage of chloroform extract;
(*d*) Percentage of alcoholic-potash extract;
(*e*) Percentage of free sulfur;
(*f*) Percentage of total sulfur, corrected;
(*g*) Percentage of ash, corrected;
(*h*) Percentage of cellulose;
(*i*) Percentage of sulfur as barium sulfate;
(*j*) Percentage of total antimony;
(*k*) Percentage of sulfur as antimony trisulfide;
(*l*) Percentage of carbon;
(*m*) Percentage of glue;
(*n*) Percentage of rubber hydrocarbon;
(*o*) Percentage of rubber, as compounded;
(*p*) Percentage of rubber by volume;
(*q*) Ratio of acetone extract to rubber as compounded;
(*r*) Ratio of sulfur to rubber as compounded;
(*s*) Specific gravity.

RUBBER SOLVENT METHOD

Rubber Solvent Method.

57. Weigh two portions "*a*" and "*b*" of from 0.5 to 1 g. each of the finely-ground sample. Extract with a mixture of 32 per cent of

acetone and 68 per cent of chloroform by volume for a minimum of 8 hours.[1] If the liquid in the extraction apparatus is still colored at the end of this time, the extraction should be continued. Remove the samples and put each into a 150-cc. lipped assay flask, add 20 to 25 cc. of the oil, cover with a watch glass and heat in an air bath at a temperature of 150 to 155° C. until solution appears complete and then 15 to 30 minutes more. Solution may be considered complete when the rubber colloid has been broken down and the oil seems quite clear. Remove the flasks from the air bath, cool to about 110° C., and add in a small stream 10 to 15 cc. of benzene, while mixing thoroughly; allow to cool and then dilute with sufficient petroleum ether to fill each flask to within about 2 cm. of the top. Mix thoroughly, cover the flasks to prevent evaporation and allow the mixture to stand overnight.

A. *Treatment of Portion "a."*

Procedure for Portion "a."

58. (*a*) Prepare a Gooch crucible with finely divided asbestos that has been previously treated with strong caustic soda solution and concentrated HCl and washed well with water. Ignite the crucible, cool and weigh; call this weight *c*. Filter the mixture by decantation through the crucible, using suction; wash well with petroleum ether, followed by warm acetone, and by a warm mixture of equal volumes of acetone and chloroform if the filtrate is dark. Remove as much as possible of the organic residue by washing; finally, wash with hot alcohol. A portion of the fillers will remain in the flask. Dry the crucible and flask with their contents for 1 hour at a temperature of 105 to 110° C. Cool and weigh. Call the weight of the flask and contents *d* and the weight of the crucible and contents *e*.

(*b*) Remove the acid-soluble compounding ingredients from the flask and Gooch crucible, collecting the solution in a 400-cc. beaker, by adding to the flask and crucible a few cubic centimeters of boiling alcohol. Allow to soak for 2 or 3 minutes and then wash two or three times with boiling water; let the flask cool, add 10 cc. of concentrated HCl and swirl the flask to bring the acid in contact with the compounding ingredients. Pour the acid from the flask into the crucible and let it stand until no more bubbles rise through the liquid. If carbonates are present, there is danger of loss by excessive frothing. This can be prevented by first adding a few drops of the acid to the crucible and sucking it through the pad. After the violent action has ceased, the remainder of the 10 cc. of acid is added. When no more gas is evolved, draw the acid through the pad and again wash with 20 cc. of acid, adding a little at a time. Wash well with hot water, and transfer as much as possible of the residue remaining in the flask to the asbestos pad. If by qualitative tests the sample was found to contain antimony, save the filtrate and washings for treatment as described in Paragraph (*c*). Dry the flask and crucible for 1 hour at 105 to 110° C., cool and weigh. Call the weight of the flask f, and that of the crucible containing the organic residue and acid-insoluble fillers, h. Burn the organic residue from the asbestos pad by igniting in a furnace at a temperature of 700° C., cool and weigh. Call this weight k. If the sample contains barytes, save the contents of the crucibles for treatment as described in Paragraph (*d*).

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[1] U. S. Bureau of Standards *Technologic Paper No. 162;* also *Rubber Age and Tire News,* pp. 445-447 (1920).

(*c*) *Determination of Sulfur Present as Antimony Trisulfide.*[1]—Dilute the filtrate in the beaker (see Paragraph (*b*)) to about 250 cc. and precipitate the antimony with H_2S. Filter off the antimony sulfide and wash the precipitate with H_2S water to which a little HCl has been added. Transfer the filter paper containing the antimony precipitate to a Kjeldahl flask, and add 12 cc. of concentrated H_2SO_4 and 5 g. of potassium sulfate. Heat the solution gently until it is colorless, dilute to 100 cc. and add 1 to 2 g. of sodium sulfite. Boil until the sulfur dioxide is driven out. Dilute to 250 to 275 cc., cool to 10 to 15° C., and titrate with standard permanganate solution. Calculate the antimony present to antimony trisulfide and express the sulfur present as antimony trisulfide in percentage of the sample and call this L.

(*d*) *Determination of Barytes.*—Transfer the contents of the crucible (see Paragraph (*c*)) to a 50-cc. porcelain crucible and fuse with 5 g. of a mixture of equal weights of sodium carbonate and nitrate. Stir well during the fusion. Cool the crucible, put it into a 250-cc. beaker, cover with distilled water and heat on the steam bath until all the solid material has been loosened from the crucible. Filter and wash the residue with warm water to free from sulfate. Wash the residue back into the beaker and dissolve in HCl (10-per-cent), using about 10 cc. excess and keeping the solution warm. Filter off the asbestos, wash well with hot water, and precipitate the barium in the solution with 10 cc. of H_2SO_4 (10-per-cent). Heat on the steam bath, filter off the precipitate, ignite and weigh the barium sulfate.

$$\text{Percentage of sulfur present as barytes} = m = \frac{100 \times \text{wt. of } BaSO_4 \times 0.1373}{\text{Wt. of sample ``}a\text{''}}$$

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[1] S. Collier, M. Levin, and J. A. Scherrer, "Determination of Antimony in Rubber Goods," *India Rubber World*, 64, p. 580 (1921).

B. Treatment of Portion "b" for Sulfur in Compounding Ingredients:

Procedure for Portion "b."

59. Treat portion "*b*" as described in Section 58(*a*), but omit the weighing of the crucible. After the pad has been dried, transfer it to the flask. The last traces of the fillers can be removed from the sides of the crucible with wads of absorbent cotton moistened with a little warm water. Add to the fillers about 10 cc. of bromine water, and swirl the flask to moisten the contents. Add 20 cc. of concentrated HNO_3 saturated with bromine. Allow to stand for 15 minutes and then heat on the steam bath for 1 hour. Transfer the contents of the flask to a 75-cc. crucible and evaporate to dryness. Complete the determination of sulfur by the method described in Section 33. Let the value for the percentage of sulfur in compounding ingredients be represented by n.

Calculations.

60. (*a*) *Calculations.*—The percentage of total inorganic compounding ingredients, corrected, equals:

$$\frac{100\ (e + d + k) - (c + f + h)}{0.5} + (m + L) - n$$

(*b*) To determine the percentage of rubber hydrocarbon subtract from 100 the sum of the percentages of acetone, chloroform, and alcoholic potash extracts, free carbon, glue, total sulfur corrected, and total inorganic compounding ingredients corrected.

TENTATIVE SPECIFICATIONS
FOR
TOLERANCES AND TEST METHODS FOR ASBESTOS YARNS[1]

Serial Designation: D 299 - 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1928.

Scope. 1. These specifications cover the tolerances and methods of testing for plain asbestos yarn and metallic asbestos yarn.

DEFINITIONS

Definitions. 2. (*a*) *Asbestos Yarn.*—Asbestos yarn is yarn consisting of: (*1*) asbestos fiber, or (*2*) asbestos and cotton fibers, or (*3*) asbestos and cotton fibers and wire.

(*b*) *Plain Asbestos Yarn.*—Plain asbestos yarn is yarn consisting of: (*1*) asbestos fiber, or (*2*) asbestos and cotton fibers.

(*c*) *Metallic Asbestos Yarn.*—Metallic asbestos yarn is yarn consisting of plain asbestos yarn twisted with brass, copper or other fine wire.

(*d*) *Cut.*—The term "cut" indicates the size of asbestos yarn. The word "cut" preceded by a number indicates, in multiples of 100 yd., the yardage per pound of single-ply yarn. For example: "5-cut" indicates that a pound of single-ply yarn so designated measures approximately 500 yd.; "10-cut" indicates a yarn that measures approximately 1000 yd. per pound.

(*e*) *Ply.*—The term "ply," applied to asbestos yarn, indicates the number of strands of single yarn twisted together to form a heavier yarn. For example: "2-ply 10-cut" indicates that each of the two strands forming the 2-ply shall be 10-cut.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. J. E. Skane, Secretary of Committee D-13 on Textile Materials, Manhattan Rubber Manufacturing Co., Passaic, N. J.

TOLERANCES

Yardage.

3. The yardage of plain, single-ply asbestos yarn shall conform to the following requirements:

SIZE DESIGNATION	NOMINAL YARDAGE PER POUND	PERMISSIBLE RANGE OF VARIATION IN YARDAGE
5-cut	500	450 to 549
6-cut	600	550 to 649
7-cut	700	650 to 749
8-cut	800	750 to 849
9-cut	900	850 to 949
10-cut	1000	950 to 1049
12-cut	1200	1150 to 1249
14-cut	1400	1300 to 1499
16-cut	1600	1500 to 1699
18-cut	1800	1700 to 1899
20-cut	2000	1900 to 2099
24-cut	2400	2300 to 2499
26-cut	2600	2500 to 2699
28-cut	2800	2700 to 2899
30-cut	3000	2900 to 3099

Size of Wire.

4. The diameter of the wire used in metallic asbestos yarn shall not vary from the size specified more than plus or minus 0.001 in.

Cotton Content.

5. (*a*) The cotton content of both plain asbestos yarn and of metallic asbestos yarn shall conform to the following requirements:

Grade A	15 to 20 per cent
Grade AA	8 to 10 " "
Grade AAA	4 to 5 " "
Grade AAAA	none

(*b*) The cotton content of metallic asbestos yarn shall be determined after all the wire has been removed from the test specimen.

METHODS OF TESTING

Cotton Content Determination.

6. The asbestos yarn shall be washed thoroughly with chloroform or ether to remove all grease, fats, and oily matter and shall be dried to constant weight at from 100 to 105° C.

A test specimen of about one gram of the extracted and dried yarn shall be weighed and placed in a combustion boat and the boat placed in a combustion furnace. The drying and absorption train shall be attached and a gentle current of thoroughly dried and purified oxygen shall be started through the apparatus. Heat shall then be applied until the combustion tube becomes dull red and the tube shall be subjected to this temperature for 15 or 20 minutes. The flow of oxygen shall then be continued for an additional 15 minutes to remove the products of combustion from the apparatus. The water from the products of combustion shall be removed by passing them through bulbs containing sulfuric acid, and then through tubes containing calcium chloride. The carbon dioxide shall be removed by absorption by passing through caustic potash (KOH) in a Vanier or other absorption bulb. The weight of the bulb being known, any increase in weight indicates the amount of carbon dioxide absorbed.

Calculation. 7. The percentage of cellulose shall be calculated from the following formula:

$$\text{Percentage of Cellulose } (C_6H_{10}O_5) = \frac{\text{Weight of } CO_2 \times 0.6137}{\text{Weight of Sample}} \times 100$$

TENTATIVE SPECIFICATIONS
FOR
TOLERANCES AND TEST METHODS FOR KNIT GOODS[1]

Serial Designation: D 231 - 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1925; REVISED, 1928.

Scope. 1. These specifications are intended to be applicable to the examination of those classes of knit goods which later enter into a manufacturing process. Where a material requires special treatment, specific methods will be described as they are developed for that material and such special tests will have precedence over these general specifications.

TOLERANCES

WIDTH

Width. 2. The width as determined by test shall not be more than 3.5 per cent above or 3.5 per cent below the specified width.

WEIGHT

Weight. 3. The weight of the fabric as determined by test shall be not more than 5 per cent over or under the specified weight.

COUNT

Count. 4. The average count of wales per inch and courses per inch as determined by test shall be not more than 5 per cent over or under the specified count.

STRENGTH (BURSTING)

Tensile Strength. 5. The average strength of the fabric as determined by test shall be not less than the specified strength.

METHODS OF TESTING

MOISTURE REGAIN

Moisture Regain. 6. (*a*) The moisture present shall be determined as follows: Portions of the samples which are taken for the determination of weight (as described in Section 10 (*b*)) weighing from 3 to 5 g. shall be placed in any suitable receptacle and the weight determined before and after drying in a ventilated oven at 105° C. The drying shall be continued until there is no change in weight, due care being taken to desiccate the receptacle and contents until cool, before weighing.

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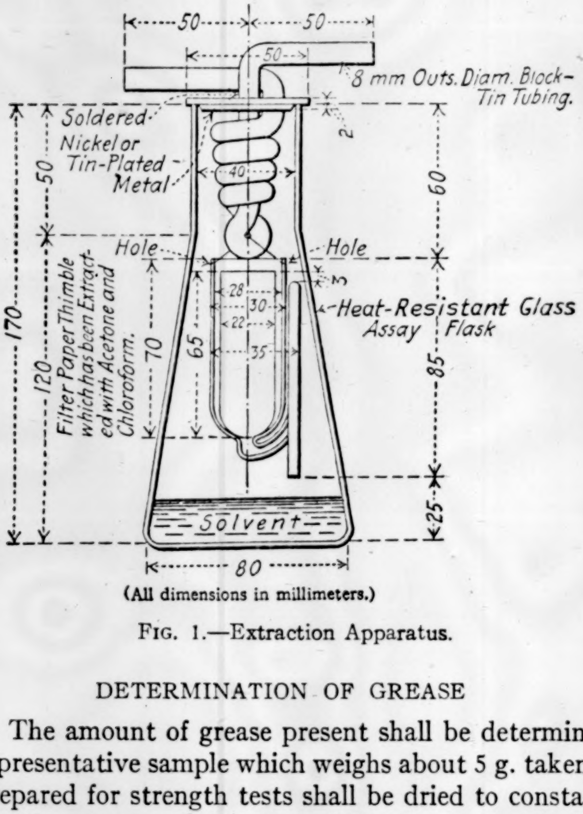
[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. J. E. Skane, Secretary of Committee D-13 on Textile Materials, Manhattan Rubber Manufacturing Co., Passaic, N. J.

(*b*) The loss in weight shall be considered moisture regain and the percentage estimated on the sample in bone-dry condition.

(*c*) Two determinations should be sufficient for ordinary purposes. Additional determinations may be required if desired.


50
50
50
8 mm Outs. Diam. Block-Tin Tubing.
2
Soldered
Nickel or Tin-Plated Metal
50
40
60
Hole
Hole
3
28
30
22
35
Heat-Resistant Glass Assay Flask
170
120
Filter Paper Thimble which has been Extracted with Acetone and Chloroform.
70
65
85
25
Solvent
80

(All dimensions in millimeters.)

FIG. 1.—Extraction Apparatus.

DETERMINATION OF GREASE

Determination of Grease.

7. (*a*) The amount of grease present shall be determined as follows: A representative sample which weighs about 5 g. taken from the samples prepared for strength tests shall be dried to constant weight in a ventilated oven at 105° C. It shall then be extracted with carbon tetrachloride in an apparatus as shown in Fig. 1. The extraction shall be continued for 8 hours and the extract dried to constant weight in a weighed flask at 105° C.

(*b*) The extract shall be considered grease and the percentage shall be reported on the dried sample.

(*c*) Two determinations of grease are usually sufficient. Additional determinations may be required if desired.

PERCENTAGE OF COTTON AND WOOL

Percentage of Cotton and Wool. 8. The amount of cotton and wool present shall be determined in accordance with the method prescribed for cotton and wool mixtures in the Tentative Methods for Identification of Textile Fibers and Their Quantitative Determination in Mixed Goods (Serial Designation: D 276 - 27 T) of the American Society for Testing Materials.[1]

WIDTH

Width. 9. (*a*) The width of the roll or piece (either split or tubular) shall be determined at five different places uniformly distributed along the full length of the roll or piece. No measurement within 8 yards of either end of the roll or piece shall be considered. The goods shall be drawn across a table without tension when the width is measured.

(*b*) The average of the five measurements shall be the width.

WEIGHT

Weight. 10. (*a*) The average square yard weight shall be determined from the weight of the roll or piece and the square yard area calculated from the length and width. The width shall be determined as described in Section 9 (*a*). For the determination of length and width a rewinding machine shall be used. The machine shall be equipped with an accurate length measuring device and the driving rolls shall travel at the same surface speed. The goods shall be drawn over the table without tension.

(*b*) *Alternate Method.*—Five samples which have been died out in staggered fashion across the roll or piece shall be weighed collectively. The die shall be square and 2 in. on a side. The material shall not be under tension as it is sampled.

(*c*) The weight shall be determined under prevailing atmospheric conditions except in the settlement of disputes. In such cases the moisture regain shall be determined as in Section 6 (*a*) on four 2 by 2-in. samples, two died from each end of the roll or piece and the average square yard weight corrected to standard conditions.

(*d*) The weight shall be reported as weight per square yard as calculated from the weight found.

THICKNESS

Thickness. 11. The thickness shall be measured by an automatic micrometer as described in Section 10 of the Standard General Methods of Testing

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 1044 (1927); also 1928 Book of A.S.T.M. Tentative Standards, p. 781.

Woven Textile Fabrics (Serial Designation: D 39) of the American Society for Testing Materials.[1]

WALES AND COURSES

Wales and Courses.

12. The number of wales and courses per inch shall be determined by counting a space of not less than 2 in. in at least five different places in the roll or piece. The material shall be laid out on a table without tension while the wales and courses are being counted.

STRENGTH (BURSTING)

Tensile Strength.

13. (*a*) The strength shall be determined on an approved type of inclination balance breaking machine. The sample shall be securely held by a ring mechanism not less than 1¾ in. in internal diameter and be drawn down against a 1-in. polished steel ball until a burst is produced. The maximum capacity of the machine shall be such that the position of the pendulum shall not be greater than 45 deg. from the vertical when the break occurs. The minimum capacity shall not be less than 20 per cent of the above maximum capacity.

(*b*) The samples shall be tested under prevailing atmospheric conditions except in the settlement of disputes. In such cases, tests shall be made upon samples which have normal moisture content, obtained by exposure for at least 4 hours to an atmosphere of 65 per cent relative humidity at a temperature of 70° F. (21° C.); or upon agreement, the tests shall be carried out upon samples which have been bone-dried as described in Section 2 of the Standard General Methods of Testing Woven Textile Fabrics (Serial Designation: D 39) of the American Society for Testing Materials.[1]

(*c*) At least 10 test pieces shall be cut, the smallest dimension of which shall be at least ½ in. greater than the outside diameter of the ring mechanism referred to in Section 13 (*a*).

(*d*) The strength shall be the average of the ten tests.

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 900.

TENTATIVE SPECIFICATIONS AND TOLERANCES
FOR
23/5/3 CARDED AMERICAN TIRE CORD[1]

Serial Designation: D 298 – 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1928.

Scope. 1. These specifications are intended to cover the requirements of a tire cord of 23/5/3 construction made from carded American cotton. The tolerances of these specifications are based on the tolerances in the Standard Specifications for Tolerances and Test Methods for Cord Tire Fabrics (Serial Designation: D 179) of the American Society for Testing Materials.[2]

NOTE.—It is recognized that manufacturers and consumers each have their own theories as to certain characteristics which the cord should have but these specifications are offered as a standard for those seeking a general all-around cord of this type.

Construction. 2. The cord shall be that known in the trade as 23/5/3 construction. The actual size of the single yarn shall be so adjusted as to give the finished size of cord specified.

Cotton. 3. These specifications are based on cord made from American Middling cotton of good hard character with a staple length of $1\frac{1}{16}$ in. Yarns shall be single carded.

Put-up. 4. The cord shall be wound on cones to the dimensions and yardage specified in the purchase contract, or if woven into tire-cord fabric shall conform to the contract specifications.

PROPERTIES

Tensile Strength. 5. The average tensile strength of the cord, conditioned, as determined by test shall not be less than 15.0 lb.

Elongation. 6. The average elongation or stretch of the cord, conditioned, as determined by test, taken at the 10-lb. load shall be 12.5 per cent in the case of cord on cones and 14.0 per cent in the case of cord from fabrics, subject to a permissible variation of plus or minus 10 per cent

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. J. E. Skane, Secretary of Committee D-13 on Textile Materials, Manhattan Rubber Manufacturing Co., Passaic, N. J.

[2] 1927 Book of A.S.T.M. Standards, Part II, p. 888.

(not less than 11.25 nor more than 13.75 per cent in the case of cord on cones, and not less than 12.6 nor more than 15.4 per cent in the case of cord from fabrics).

Size or Yardage. 7. The average size of the cord, conditioned, as determined by test shall be 1.25, or the yardage per pound, subject to a permissible variation of plus or minus 3.0 per cent (average not less than 1018 nor more than 1082 yd. per lb.), shall be 1050 yd. per lb.

Thickness (Gage). 8. The average thickness or gage of the cord, as determined by test shall be 0.033 in., subject to a permissible variation of plus or minus 3.5 per cent (not less than 0.032 nor more than 0.034 in.).

Twist. 9. (*a*) The single yarn shall be spun with right-hand twist, with a twist multiple of four times the square root of the actual single yarn size.

(*b*) The forming twist of the 23/5 ply cord shall be right hand in direction and shall be made with 18 turns per inch subject to a permissible variation of plus or minus 5 per cent (not less than 17.0 nor more than 19.0 turns per inch).

(*c*) The final twist of the 23/5/3 ply cord shall be left hand in direction and shall be made with 8 turns per inch subject to a permissible variation of plus or minus 4 per cent (not less than 7.7 nor more than 8.3 turns per inch).

NOTE.—Direction of twist is defined in the Standard Definitions of Terms Relating to Textile Materials (Serial Designation: D 123) of the American Society for Testing Materials.[1]

METHODS OF TESTING

Methods of Testing. 10. All tests shall be in accordance with the methods of testing prescribed in the Standard Specifications for Tolerances and Test Methods for Cord Tire Fabrics (Serial Designation: D 179) of the American Society for Testing Materials.[2]

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 905.

[2] *Ibid.*, p. 888.

TENTATIVE DEFINITIONS OF TERMS RELATING TO TEXTILE MATERIALS[1]

Serial Designation: D 123 - 28 T

This is a **Tentative Standard,** published for the purpose of eliciting **criticism** and suggestions, and as such is subject to annual revision.

ISSUED, 1926; REVISED, 1927, 1928.

Fabrics

Breaker Tire Fabric.—An open-woven, cotton fabric. There are three constructions, namely, (1) Plied yarns in both warp and filling; (2) Hawser cords in both warp and filling; and (3) Hawser cords in warp; singles yarn in filling.

Sheeting.—A light or medium weight plain-weave cotton fabric, woven with a single yarn from 12's to 30's.

Osnaburg.—A coarse, low count, plain-weave cotton fabric, using yarns 3's to 12's, weight 6 to 10 oz. per sq. yd., thread count approximately 30 to 38 warp and 28 to 32 filling per inch.

Airplane Fabric (Cotton).—Plain-weave cotton fabric, well woven, practically without imperfections, from mercerized yarns; width 36 to 56 in., maximum weight 4.5 oz. per sq. yd. and 80 to 84 ends and picks per inch.

NOTE.—This definition is taken from the United States Government Master Specification for Mercerized Cotton Airplane Cloth, Grade A, F. S. B. Specification No. 258a.

Awning Cloth.—Heavy cotton fabric, generally plain weave or twilled from heavy yarns, 14's to 16's warp, 10's to 16's filling.

NOTE.—Awning Cloth is generally made in striped patterns, woven or printed.

Tent Duck.—A plain-weave cotton fabric from plied yarn, 2 or 3 ply warp, 2 or 3 ply filling, 28 to 30 in. wide and weighing 8 to 16 oz. per sq. yd., yarn count 46's to 64's warp, 34's to 60's filling.

NOTE.—This definition is taken from the United States Government Master Specification for Tent Duck (Special Construction for Bleaching or Dyeing, Gray), F. S. B. Specification No. 160.

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[1] Criticisms of these Tentative Definitions are solicited and should be directed to Mr. J. E. Skane, Secretary of Committee D-13 on Textile Materials, Manhattan Rubber Manufacturing Co., Passaic, N. J.

These tentative definitions when adopted as standard, will be added to the present Standard Definitions of Terms Relating to Textile Materials (Serial Designation: D 123), 1927 Book of A.S.T.M. Standards, Part II, p. 905.

Webbing, Elastic.—A strong narrow fabric made with rubber threads as part of warp or filling or of both.

Dungaree.—A heavy cotton cloth woven in the 2/1 twill weave from dyed warp and filling yarns, woven in narrow widths, usually 28 in., approximately 68 warp by 52 filling, from 20's warp and 20's filling.

NOTE.—Dungaree is also known as "4-end twill weave."

Burlap.—A coarse, heavy, plain-weave fabric woven from coarse yarn made from jute, hemp or flax.

Felt.—A fabric of fibers united without weaving, by the application of heat, moisture and pressure or by mechanical interlacing.

Imperfections

Cockled.—A curliness or crimpiness, most marked in fine goods, appearing in fabrics when different sizes of yarn or tensions on section of the warp are accidentally introduced.

Broken Ends.—A fault caused by broken warp yarns.

Broken Picks.—A fault caused by broken or run-out filling yarn.

Loop Knot.—Snarl or curl produced by a weft yarn receding upon itself.

Yarns and Cords

Hawser Twist.—The formation of cotton twine made with the first and second twist in the same direction and the third twist in the opposite direction.

Cable Twist.—The formation of cotton twine in which each successive twist is in opposite direction to the preceding twist.

Hard Twist.—An amount of twist which is considerably more than the usual number of turns per inch contained in warp yarns.

Twine.—A cord made up of two or more yarns of medium twist with ply twist in opposite direction, for use in tying, binding, coarse sewing, etc.

Rope.—A cord made from cotton, hemp, flax, jute, etc., measuring ¼ to 5 in. in diameter.

General Definitions

Regain (Moisture Regain).—The percentage of moisture present in a textile material calculated on its absolute dry weight.

Gage.—In the case of knit goods, the closeness of the wales, that is, the longitudinal row of loops per inch, a measure of the fineness of the fabric. It is expressed by the number of needles in 1½ in.

Laid Fabric.—A construction in cotton fabrics made without filling yarn, the warp yarn being held together in parallel relationship in the same plane by means of rubber latex or other binding material.

Holland.—A finish, glazed or unglazed, with oil and a filling material, applied to plain-weave cotton fabrics to make them opaque or semi-opaque; resembling a beattled linen fabric formerly known as "Holland."

Book-Fold.—The fabric is doubled selvage to selvage then folded back and forth upon itself in predetermined lengths. When the piece is completed, the fold-edges on each side are folded to the center and the piece is folded once more upon itself so that the fold-edges are inside, forming a compact package as long as one-half the width of the goods.

Shoe-Fold.—The fabric is folded from both ends into twelve or sixteen folds to the piece, the length of the fold depending upon the length of the piece.

TENTATIVE SPECIFICATIONS
FOR
THERMOMETERS FOR ENGLER VISCOSIMETERS[1]

Serial Designation: D 300 - 28 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1928.

The thermometers shall conform to the following requirements. These specifications cover thermometers for use in the Engler Viscosimeter graduated in Centigrade degrees, the ranges being 22.5 to 27.5° C., 37.5 to 42.5° C., 47.5 to 52.5° C., and 97.5 to 102.5° C.

TYPE: Etched stem, glass.

LIQUID: Mercury.

RANGES AND SUBDIVISIONS: 22.5 to 27.5° C. in 0.1° C. for tests at 25° C., 37.5 to 42.5° C. in 0.1° C. for tests at 40° C., 47.5 to 52.5° C. in 0.1° C. for tests at 50° C., 97 5 to 102.5° C. in 0.1° C. for tests at 100° C.

TOTAL LENGTH: 206 to 210 mm.

STEM: Plain front, enamel back, suitable thermometer tubing. Diameter 5.5 to 6.5 mm. A modification of the standard Engler Thermometer bushing shall be provided as follows: The bushing shall have a threaded detachable head. The tubular shank of the bushing shall be cemented to the stem of the thermometer in such a position that the distance from the bottom of the bulb to the underside of the detachable head shall be 90 mm. when the head is attached (screwed home).

BULB: Corning normal or equally suitable Thermometric Glass.
Length 10.5 to 14.5 mm.
Diameter 8.5 to 9.5 mm.

DISTANCE TO LOWEST SPECIFIED GRADUATION FROM BOTTOM OF BULB: 100 to 120 mm.

DISTANCE TO HIGHEST SPECIFIED GRADUATION FROM TOP OF THERMOMETER: 30 to 50 mm.

CONTRACTION CHAMBER: To be a long narrow type, top to be not more than 60 mm. above bottom of bulb, mercury to stand in contraction chamber at 0° C.

EXPANSION CHAMBER: To permit heating the thermometer 50° C. above highest temperature on scale, and in all cases to permit heating to 100° C.

FILLING ABOVE MERCURY: Nitrogen Gas.

TOP FINISH: Glass Ball.

GRADUATION: All lines, figures and letters clear cut and distinct. The first and each succeeding 0.5° C. line to be longer than the remaining lines. Graduations to be numbered each multiple of 1° C.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. C. S. Reeve, Secretary of Committee D-15 on Thermometers The Barrett Co., 255 Glenwood Ave., Leonia, N. J.

IMMERSION: 90 mm.

SPECIAL MARKING: "A.S.T.M." Viscosity test points to be numbered in full figures and in red, other graduations and figures in black. The stem is to be marked on the back with a serial number, manufacturer's name or trade mark and "90 mm. immersion A.S.T.M. Engler."

SCALE ERROR: The error at any point of the scale shall not exceed 0.1° C.

STANDARDIZATION: The thermometers are to be standardized for the condition of 90 mm. immersion.

CASE: Each thermometer shall be supplied in a suitable case on which shall appear the marking "A.S.T.M. Engler Viscosimeter Thermometer" and the range.

TENTATIVE DEFINITION OF THE TERM SCREEN (SIEVE)[1]

Serial Designation: E 13 - 28 T

This is a **Tentative Standard**, published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1925; REVISED, 1926, 1928.

Screen (Sieve).—A plate or sheet or a woven cloth, or other device, with regularly spaced apertures of uniform size, mounted in a suitable frame or holder, for use in separating material according to size.

NOTE 1.—The shape and spacing of apertures, size of wires or threads, thickness of plate or sheet, allowable variations and similar properties should be taken care of in specifications.

NOTE 2.—In mechanical analysis testing work, when not otherwise specified, the term "sieve" shall apply to an apparatus in which the apertures are rectangular, and the term "screen" shall apply to an apparatus in which the apertures are circular.

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[1] Criticisms of this Tentative Definition are solicited and should be directed to Mr. L. R. Ferguson, Chairman of the Sub-Committee, of Committee E-8, on Definitions of Sieve and Screen, Texas Portland Cement Co., 1401 Santa Fe Building, Dallas, Tex.

TENTATIVE REVISIONS
OF
A.S.T.M. STANDARDS

Tentative revisions of A.S.T.M. Standards are printed for one or more years with a view of eliciting criticism, of which the committee concerned will take due cognizance before recommending final action.

Members of the Society and others are invited to direct written criticisms of any of these Tentative Revisions to the officer of the appropriate committee, whose name and address appear in the footnote in connection with each revision.

TENTATIVE REVISIONS OF A.S.T.M. STANDARDS

A. FERROUS METALS

STANDARD SPECIFICATIONS FOR STEEL TRACK SPIKES

(Serial Designation: A 65 - 24)[1]

A revision in the form of separate tentative specifications entitled "Specifications for Soft Steel Track Spikes (A 65 - 26 T)"[2] is intended to replace the present standard specifications.

STANDARD SPECIFICATIONS FOR STRUCTURAL STEEL FOR BRIDGES

(Serial Designation: A 7 - 24)[1]

Section 3.—Add a new Paragraph (*b*) to read as follows:

(*b*) When copper steel is specified, the following requirement as to copper shall govern:

Copper........................... not less than 0.20 per cent

Section 4.—Change to read as follows by the addition of the italicized words:

4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur *and also copper, when copper steel is specified.* This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative and *the percentages of phosphorus and sulfur and also copper, when copper steel is specified,* shall conform to the requirements specified in Section 3 (*a*) *and* (*b*).

Table II.—Add a note to Table II on Permissible Overweights of Rectangular Plates Ordered to Thickness, to read as follows:

Note.—The weight of individual plates ordered to thickness shall not exceed the nominal weight by more than one and one-third the amount given in this table.

STANDARD SPECIFICATIONS FOR STRUCTURAL NICKEL STEEL

(Serial Designation: A 8 - 24)[1]

Table II.—Add a note to Table II on Permissible Overweights of Rectangular Plates Ordered to Thickness, to read as follows:

Note.—The weight of individual plates ordered to thickness shall not exceed the nominal weight by more than one and one-third the amount given in this table.

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[1] 1927 Book of A.S.T.M. Standards, Part I. Criticisms of this revision are solicited and should be directed to Mr. V. H. Lawrence, Secretary of Committee A-1 on Steel, Alan Wood Iron and Steel Co., Conshohocken, Pa.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, p. 631 (1926); also 1928 Book of A.S.T.M. Tentative Standards, p. 21.

STANDARD SPECIFICATIONS FOR STRUCTURAL STEEL FOR BUILDINGS

(SERIAL DESIGNATION: A 9 - 24)[1]

Section 2.—Add a new Paragraph (*b*) to read as follows:

(*b*) When copper steel is specified, the following requirement as to copper shall govern:

Copper.......................... not less than 0.20 per cent

Section 3.—Change to read as follows by the addition of the italicized words:

3. (*a*) A carbon determination *and also copper, when copper steel is specified*, shall be made of each melt of bessemer steel, and determinations for manganese, phosphorus and sulfur representing the average of the melts applied for each 12-hour period.

(*b*) An analysis of each melt of open-hearth steel shall be made for carbon, manganese, phosphorus and sulfur *and also copper, when copper steel is specified.*

(*c*) These analyses shall be made by the manufacturer from test ingots taken during the pouring of each melt. The chemical composition thus determined shall be reported to the purchaser or his representative and *the percentages of phosphorus and sulfur, and also copper, when copper steel is specified*, shall conform to the requirements specified in Section 2 (*a*) *and* (*b*).

Table II.—Add a note to Table II on Permissible Overweights of Rectangular Plates Ordered to Thickness, to read as follows:

NOTE.—The weight of individual plates ordered to thickness shall not exceed the nominal weight by more than one and one-third the amount given in this table.

STANDARD SPECIFICATIONS FOR STRUCTURAL SILICON STEEL

(SERIAL DESIGNATION: A 94 - 27)[1]

Table II.—Add a note to Table II on Permissible Overweights of Rectangular Plates Ordered to Thickness, to read as follows:

NOTE.—The weight of individual plates ordered to thickness shall not exceed the nominal weight by more than one and one-third the amount given in this table.

STANDARD SPECIFICATIONS FOR BILLET-STEEL CONCRETE REINFORCEMENT BARS

(SERIAL DESIGNATION: A 15 - 14)[1]

Section 2.—Omit Paragraph (*a*) reading as follows, designating Paragraph (*b*), as Section 2:

(*a*) The structural-steel grade shall be used unless otherwise specified.

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[1] 1927 Book of A.S.T.M. Standards, Part I. Criticisms of this revision are solicited and should be directed to Mr. V. H. Lawrence, Secretary of Committee A-1 on Steel, Alan Wood Iron and Steel Co., Conshohocken, Pa.

Section 5.—Change to read as follows by the addition of the italicized words and figures:

5. The steel shall conform to the following requirements as to chemical composition:

Phosphorus	Bessemer	not over 0.10 per cent
	Open-hearth *Basic*	" " 0.05 "
	Open-hearth Acid	" " *0.08* "

Section 8.—Change the requirement for tensile strength of intermediate grade of both plain and deformed reinforcement bars as given in the table of Paragraph (*a*) from "70,000 to 85,000" to read "70,000 to 90,000," and add to the requirement for elongation in 8 in. of intermediate grade plain bars the provision "but not less than 16 per cent" and to the requirement for intermediate grade deformed bars "but not less than 14 per cent," both of these provisions to be subject to the modifications of Section 9.

STANDARD SPECIFICATIONS FOR IRON AND STEEL CHAIN

(SERIAL DESIGNATION: A 56 – 24)[1]

A revision in the form of separate tentative specifications entitled "Specifications for Iron and Steel Chain (A 56 – 28 T)"[2] is intended to replace the present standard specifications.

STANDARD SPECIFICATIONS FOR STAYBOLT, ENGINE-BOLT AND EXTRA-REFINED WROUGHT-IRON BARS

(SERIAL DESIGNATION: A 84 – 27)[1]

Section 7 (a).—Change to read as follows by the addition of the italicized words and the omission of those in brackets:

(a) Grade A.—For bars ⅞ in. [or under] in diameter, a reduction in the minimum elongation in 8 in. specified in Section 6 (a) shall be permitted, but in no case shall the elongation be less than 28 per cent. *For bars ¾ in. or under in diameter, the elongation shall not be less than 25 per cent.*

STANDARD SPECIFICATIONS FOR GRAY-IRON CASTINGS

(SERIAL DESIGNATION: A 48 – 18)[3]

Section 5. (a).—Change to read as follows by the addition of the italicized figures and the omission of those in brackets:

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[1] 1927 Book of A.S.T.M. Standards, Part I. Criticisms of this revision are solicited and should be directed to Mr. G. H. Woodroffe, Secretary of Committee A-2 on Wrought Iron, Reading Iron Co., Reading, Pa.

[2] See p. 697.

[3] 1927 Book of A.S.T.M. Standards, Part I. Criticisms of this revision are solicited and should be directed to Mr. F. B. Coyle, Secretary of Committee A-3 on Cast Iron, 574 Bergen Ave., Jersey City, N. J.

5. (*a*) The transverse test specimens (arbitration test bars) specified in Section 7 (a), when placed horizontally upon supports [12] *18* in. apart and tested under a centrally applied load, shall conform to the following minimum requirements, interpreted in accordance with Section 9:

	CLASS OF CASTING		
	LIGHT	MEDIUM	HEAVY
Load at center, lb	[2500] *1500*	[2900] *1750*	[3300] *2000*
Deflection at center, in	[0.10] *0.20*	[0.10] *0.20*	[0.10] *0.20*

Figure 1.—Delete this figure.

Figure 2.—Delete this figure.

Section 7.—Omit the present Section 7 comprising a description of the arbitration test bar and tension test specimen and insert a new section to read as follows:

7. (*a*) *Arbitration Test Bar.*—The arbitration test bar shall be in accordance with the Tentative Specifications for the Arbitration Test Bar and Tension Test Specimen for Cast Iron (Serial Designation: A 124 – 28 T) of the American Society for Testing Materials.

(*b*) *Tension Test Specimen.*—When tension tests are specified, the tension test specimen shall conform to the requirements specified in the Tentative Specifications D 124 – 28 T.

STANDARD SPECIFICATIONS FOR CAST-IRON SOIL PIPE AND FITTINGS

(SERIAL DESIGNATION: A 74 – 18)[1]

Section 4.—Change to read as follows by the addition of the italicized figures and the omission of those in brackets:

4. The transverse test specimens (arbitration test bars) specified in Section 6, when placed horizontally upon supports [12] *18* in. apart and tested under a centrally applied load, shall conform to the following minimum requirements:

Average load at center, lb	[2500] *1500*
Average deflection at center, in	[0.10] *0.20*

Figure 1.—Delete this figure.

Section 6.—Omit the present Section 6 comprising a description of the arbitration test bar mold and insert a new section to read as follows:

6. Arbitration Test Bar.—The arbitration test bar shall be in accordance with the Tentative Specifications for the Arbitration Test Bar and Tension Test Specimen for Cast Iron (Serial Designation: A 124 – 28 T) of the American Society for Testing Materials.

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[1] 1927 Book of A.S.T.M. Standards, Part I. Criticisms of this revision are solicited and should be directed to Mr. F. B. Coyle, Secretary of Committee A-3 on Cast Iron, 574 Bergen Ave., Jersey City, N. J.

STANDARD SPECIFICATIONS FOR HIGH-TEST GRAY-IRON CASTINGS

(SERIAL DESIGNATION: A 88 - 24)[1]

Section 4 (a).—Change to read as follows by the addition of the italicized figures and the omission of those in brackets:

4. (*a*) The transverse test specimens (arbitration test bars) specified in Section 6 (*a*), when placed horizontally upon supports [12] *18* in. apart and tested under a centrally applied load, shall withstand a minimum load of [3800] *2250* lb. and deflect under this load at least [0.12] *0.24* in. at the center.

Figure 1.—Delete this figure.

Figure 2.—Delete this figure.

Section 6.—Omit the present Section 6 comprising a description of the arbitration test bar and tension test specimen and insert a new section to read as follows:

6. (*a*) *Arbitration Test Bar.*—The arbitration test bar shall be in accordance with the Tentative Specifications for the Arbitration Test Bar and Tension Test Specimen for Cast Iron (Serial Designation: A 124 - 28 T) of the American Society for Testing Materials.

(*b*) *Tension Test Specimen.*—When tension tests are specified, the tension test specimen shall conform to the requirements specified in the Tentative Specifications D 124 - 28 T.

STANDARD METHODS OF CHEMICAL ANALYSIS OF PLAIN CARBON STEEL

(SERIAL DESIGNATION: A 33 - 24)[2]

A revision in the form of separate tentative methods of sampling entitled "Methods of Sampling Rolled and Forged Steel Products for Check Analysis (A 33 - 28 T)"[3] is intended to be added to the present standard methods.

B. NON-FERROUS METALS

STANDARD SPECIFICATIONS FOR BRONZE BEARING METAL IN INGOT FORM

(SERIAL DESIGNATION: B 31 - 21)[4]

Section 3.—Replace the present table of requirements for chemical composition with the following:

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[1] 1927 Book of A.S.T.M. Standards, Part I. Criticisms of this revision are solicited and should be directed to Mr. F. B. Coyle, Secretary of Committee A-3 on Cast Iron, 574 Bergen Ave., Jersey City, N. J.

[2] 1927 Book of A.S.T.M. Standards, Part I. Criticisms of this revision are solicited and should be directed to Mr. V. H. Lawrence, Secretary of Committee A-1 on Steel, Alan Wood Iron and Steel Co., Conshohocken, Pa.

[3] See p. 756.

[4] 1927 Book of A.S.T.M. Standards, Part I. Criticisms of this revision are solicited and should be directed to Mr. E. E. Thum, Secretary of Committee B-2 on Non-Ferrous Metals and Alloys, *The Iron Age*, 239 W. Thirty-ninth St., New York City.

Alloy, Grade No.	Copper, per cent	Tin, per cent	Lead, per cent	Phosphorus, per cent	Impurities, maximum, per cent						Constituents Other than Copper, Tin, Lead and Phosphorus, per cent
					Zinc	Iron	Nickel	Antimony	Aluminum	Sulfur	
1........	85	10	5	0.70[a]	0.25	0.25	0.25	0.75	none	0.05	0.50 - 1.00
2........	80	10	10	0.70[a]	0.50	0.25	0.25	0.75	none	0.05	0.75 - 1.25
3........	80	10	10	0.05[b]	2.00	0.25	0.25	0.75	none	0.05	2.50 - 3.00
4........	77	8	15	0.25[b]	0.50	0.25	0.25	0.75	none	0.05	0.75 - 1.25
5........	73	7	20	0.05[b]	0.50	0.25	0.25	0.75	none	0.05	1.00 - 1.25
6........	70	5	25	none	0.50	0.25	0.25	0.75	none	0.05	1.00 - 1.25

[a] Minimum. [b] Maximum.

Section 4.—In the table of permissible variations for the percentage of elements specified over 10 per cent, change the permissible variations over and under the specified value from "1.50 per cent" to "2.00 per cent."

STANDARD SPECIFICATIONS FOR CARTRIDGE BRASS

(SERIAL DESIGNATION: B 19 - 19)[1]

Section 4.—Change the requirement for copper from "66.5-69.5 per cent" to "68.0-71.0 per cent."

Section 6.—Omit Paragraph (*a*) reading as follows, designating Paragraph (*b*) as Section 6:

6. (*a*) Analyses of separate pieces may be made by the purchaser. The copper, lead, and iron contents thus determined shall be as follows:

Copper..........................	66.0 - 70.0 per cent
Lead..............................	not over 0.10 "
Iron...............................	" " 0.08 "

Section 7.—Change this section from its present form, namely:

7. The brass shall be so annealed that the average of ten Brinell hardness readings from a lot will be within the limits of 51 to 65, using a 10-mm. ball and a pressure of 500 kg. No individual test shall exceed the limits of 50 to 69 (Note 1).

to read as follows:

7. The brass shall be so annealed that the average of ten Brinell hardness readings from a lot will be within the limits of 49 to 65, using a 10-mm. ball and a pressure of 500 kg. (Notes 1 and 3).

Explanatory Note.—Add a third note to read as follows;

NOTE 3.—These specifications are intended to cover the requirements of commercial practice which do not in all cases agree with those of the Ordnance Department. These departures involve only the degree of final annealing.

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[1] 1927 Book of A.S.T.M. Standards, Part I. Criticisms of this revision are solicited and should be directed to Mr. E. E. Thum, Secretary of Committee B-2 on Non-Ferrous Metals and Alloys. *The Iron Age*, 239 W. Thirty-ninth St., New York City.

STANDARD SPECIFICATIONS FOR CARTRIDGE BRASS DISKS

(SERIAL DESIGNATION: B 20 – 19)[1]

Section 3.—In Paragraph (*a*) change the gage tolerances to read as follows by the addition of the italicized figures and the omission of those in brackets:

Gage	Permissible Variation, in.,
Up to 0.150 in., incl	[±0.0025] *−0, +0.0050*
Over 0.150 to 0.300 in., incl	[±0.003] *−0, +0.006*
Over 0.300 to 0.400 in., incl	[±0.004] *−0, +0.008*
Over 0.400 in	[±0.005] *−0, +0.010*

Add a new heading and a new section, to read as follows:

PHYSICAL PROPERTIES AND TESTS

4. The brass shall be so annealed that the average of ten Brinell hardness readings from a lot will be within the limits of 49 to 65, using a 10-mm. ball and a pressure of 500 kg.

NOTE.—These specifications are intended to cover the requirements of commercial practice which do not in all cases agree with those of the Ordnance Department. These departures involve only the degree of final annealing.

STANDARD SPECIFICATIONS FOR FREE-CUTTING BRASS ROD FOR USE IN SCREW MACHINES

(SERIAL DESIGNATION: B 16 – 18)[1]

Section 3.—Change the requirement for lead content from "2.25 – 3.25 per cent" to "2.50 – 3.75 per cent," and change the requirement for materials other than copper, lead and zinc from "not over 0.25 per cent" to "not over 0.50 per cent."

Section 5.—Omit Paragraph (*a*) reading as follows, designating Paragraph (*b*) as Section 5:

5. (*a*) Analyses of separate rods may be made by the purchaser. The copper and lead contents thus determined shall lie within the following limits:

Copper	59.4 – 63.6 per cent
Lead	1.8 – 3.9 "

Section 6.— Change from its present form: namely,

6. Rods or bars shall bend cold through an angle of 120 deg. around a pin the diameter of which is equal to twice the diameter or thickness of the rod or bar, without fracture (Note 3).

to read as follows:

6. Rods or bars shall stand being bent cold through an angle of 120 deg. around a pin, the diameter of which is equal to twice the diameter of the round rods or four times the thickness of other shapes, without fracturing (Note 3).

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[1] 1927 Book of A.S.T.M. Standards Part I. Criticisms of this revision are solicited and should be directed to Mr. E. E. Thum, Secretary of Committee B-2 on Non-Ferrous Metals and Alloys, *The Iron Age*, 239 W. Thirty-ninth St., New York City.

Section 8.—Replace the present table of permissible variations by the following:

Diameter, or Distance Between Parallel Faces	Permissible Variation	
	Rounds	Other Shapes
Up to ½ in., inclusive	±0.0015 in.	±0.003 in.
Over ½ to 1 in., inclusive	±0.002 in.	±0.004 in.
Over 1 to 2½ in., inclusive	±0.0025 in.	±0.005 in.
Over 2½ in.	±0.15 per cent	±0.30 per cent

STANDARD SPECIFICATIONS FOR NAVAL BRASS RODS FOR STRUCTURAL PURPOSES

(Serial Designation: B 21 – 27)[1]

Section 10.—Revise the table of permissible variations to agree with the table of permissible variations recommended for Specifications B 16 – 18 above.

STANDARD SPECIFICATIONS FOR SEAMLESS ADMIRALTY CONDENSER TUBES AND FERRULE STOCK

(Serial Designation: B 44 – 24)[1]

Section 12.—Insert under the Sub-Heading on Permissible Variations in Dimensions, a new Section 12 to read as follows, renumbering the subsequent sections accordingly:

12. *Diameter.*—The outside diameter of the tubes shall not vary from that specified by more than the following amounts, as measured by "go" and "no go" ring gages:

Nominal Diameter, in.	Permissible Variation, in.
Up to 0.500, inclusive	plus or minus 0.002
Over 0.500 to 0.740, inclusive	" " " 0.0025
Over 0.740 to 1.000, "	" " " 0.003
Over 1.000 to 1.250, "	" " " 0.0035
Over 1.250 to 1.500, "	" " " 0.004

STANDARD METHODS OF CHEMICAL ANALYSIS OF MANGANESE BRONZE

(Serial Designation: B 27 – 19)[1]

Under the Determination of Manganese by the Persulfate Method, change the description under Method from its present form: namely,

In a 250-cc. Erlenmeyer flask dissolve 1 g. of bronze in 24 cc. of the "solution for dissolving." Allow to stand on a steam bath or hot plate until entirely dissolved, and until the oxides of nitrogen are expelled. Add 15 cc. of $AgNO_3$ solution and 20 cc. of ammonium persulfate and leave on the steam bath until the solution has developed a full permanganate color and no bubbles can be seen to come off when the flask is given a whirling motion. Cool to below 25° C. in running water, and add 50 cc. of cold water. Titrate with standard sodium-arsenite solution to the disappearance of the pink color.

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[1] 1927 Book of A.S.T.M. Standards, Part I. Criticisms of this revision are solicited and should be directed to Mr. E. E. Thum, Secretary of Committee B-2 on Non-Ferrous Metals and Alloys, *The Iron Age*, 239 W. Thirty-ninth St., New York City.

to read as follows:

Adjust the size of sample to the expected percentage so that the portion taken does not contain more than 0.002 g. manganese. Place it in a 250-cc. Erlenmeyer flask with 24 cc. of the "solution for dissolving" and heat until solution is complete. Boil until oxides of nitrogen are expelled. Dilute to 100 cc. with boiling-hot water, add 20 cc. of $AgNO_3$ solution and 30 cc. of the persulfate solution, then remove to a moderately warm place to stand for a few minutes for complete development of the permanganic acid. Cool to below 25° C., and titrate with the standard arsenite solution to the disappearance of the pink color.

C. CEMENT, LIME, GYPSUM AND CLAY PRODUCTS

STANDARD SPECIFICATIONS AND TESTS FOR PORTLAND CEMENT

(SERIAL DESIGNATION: C 9 – 26)[1]

A revision in the form of a separate tentative specification entitled "Specifications and Tests for Compressive Strength of Portland-Cement Mortars (C 9 – 16 T)"[2] is intended to become a part of the present standard specifications.

STANDARD SPECIFICATIONS FOR HYDRATED LIME FOR STRUCTURAL PURPOSES

(SERIAL DESIGNATION: C 6 – 24)[3]

Section 12.—Change the second and fifth paragraphs from their present form: namely,

The lime shall be made into a stiff putty with water and permitted to soak over night. It shall be molded in a rubber ring such as is used with a Vicat needle, resting the specimen on a glass plate.

If the penetration is less than standard, the sample may be removed from the mold, mixed with more water, and retested. If the penetration is more than standard, the sample shall be discarded and a new one prepared.

to read respectively as follows:

The lime shall be made into a stiff putty with water, stirred vigorously with a trowel or spatula for three minutes and permitted to soak over night.

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[1] 1927 Book of A.S.T.M. Standards, Part II. Criticisms of this revision are solicited and should be directed to Mr. F. H. Jackson, Secretary of Committee C-1 on Cement, U. S. Bureau of Public Roads, Washington, D. C.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. XX, Part I, p. 599 (1920); also 1928 Book of A.S.T.M. Tentative Standards, p. 206.

[3] 1927 Book of A.S.T.M. Standards, Part II. Criticisms of this revision are solicited and should be directed to Mr. W. V. Brumbaugh, Secretary of Committee C-7 on Lime, National Lime Association, Washington, D. C.

It shall be stirred vigorously with a trowel or spatula for three minutes, molded in a rubber ring such as is used with a Vicat needle, resting the specimen on a glass plate.

If the penetration is less than standard, the sample may be removed from the mold, mixed with more water, stirred vigorously with a trowel or spatula for three minutes, and retested. If the penetration is more than standard, the sample shall be discarded and a new one prepared.

Section 13.—Change the first paragraph to read as follows by the addition of the italicized words:

13. Plasticity shall be determined by means of the apparatus shown in Fig. 1 as follows: Three hundred grams of the sample shall be mixed with enough water to form a thick putty *and stirred vigorously for 3 minutes with a trowel or spatula.* After aging in a vessel covered with a damp cloth for not less than 16 nor more than 24 hours, this putty shall be *stirred vigorously for 3 minutes with a trowel or spatula and* adjusted to standard consistency, as defined in Section 12, with a permissible variation of ±5 mm.

Omit the last paragraph of this section reading as follows:

After each test, the porcelain base plate shall be washed with hot water, treated with dilute hydrochloric acid to remove any lime from the surface pores, washed again with water, to remove the acid, dried by heating about 100° C., and cooled to room temperature before it is used again.

Figure 1.—Revise the constants given under the illustration of the Emley Plasticimeter by changing the first line to read as follows:

Absorption of porcelain base plate.—Minimum 40 g. in 24 hours. For rate of absorption of base plates, see Section 15.

Add two new sections, numbered 14 and 15, to read as follows, renumbering the present Section 14 to read Section 16:

14. *Cleaning and Care of Base Plates.*—In making plasticity determinations much of the success attainable depends upon the condition of the base plates. Continued use of the plates without proper cleaning results in clogging of the pores, with reduction in the rate of absorption. After a plate has been used the excess lime shall be wiped off and the plate immersed in clear water for not less than two hours, after which it shall be transferred without drying to a dilute solution of hydrochloric acid (1:9) where it shall be kept immersed for another two hours. It should then be transferred to a receptacle containing running water for at least one hour. The plate is then free of acid and after the removal of excess water should be placed in an oven at a temperature of between 100 and 110° C. overnight for drying. Before using, the plate shall be cooled to room temperature.

15. *Absorption of Plasticimeter Base Plates.* (*a*) *Total Absorption.*—Plasticimeter base plates when immersed in water at room temperature for a period of 24 hours shall absorb not less than 40 g. of water. Before making the determination the plates shall be dried overnight in an oven at a temperature of between 100 and 110° C. and permitted to cool to room temperature. After

immersion and before weighing, the excess water shall be wiped off with a damp cloth.

(*b*) *Rate of Absorption.*[a]—When tested over an area 2¾ in. in diameter the water absorbed shall be in accordance with the following:

	WATER ABSORBED, CC.
First Minute	8 to 14
Second Minute	5 to 7½
Third Minute	4 to 6½
Fourth Minute	4 to 6
Fifth Minute	3½ to 5½

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[a] A convenient apparatus for determining the rate of absorption consists of a burette sealed onto an inverted glass funnel from which the stem has been removed. The diameter of the larger end of the funnel shall be ground so as to be 2¾ in. in internal diameter. The funnel may be attached to the plate on which the measurement is being made by melted paraffin. The paraffin should not be too hot. A little experience will indicate when it is of the proper consistency.

STANDARD SPECIFICATIONS FOR PAVING BRICK

(SERIAL DESIGNATION: C 7 – 15)[1]

A revision in the form of separate tentative specifications entitled "Specifications for Paving Brick (C 7 – 28 T)"[2] is intended to replace the present standard specifications.

STANDARD SPECIFICATIONS FOR CEMENT-CONCRETE SEWER PIPE

(SERIAL DESIGNATION: C 14 – 24)[3]

Section 1.—Add the following footnote:

Caution.—The consumer or purchaser is cautioned against using cement-concrete pipe where the sewage shows an acid reaction.

STANDARD SPECIFICATIONS AND TESTS FOR HOLLOW BURNED-CLAY LOAD-BEARING WALL TILE

(SERIAL DESIGNATION: C 34 – 27)[4]

Section 2 (*a*).—Change the wording and the absorption requirements of this section from the present form: namely,

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[1] 1927 Book of A.S.T.M. Standards, Part II. Criticisms of this revision are solicited and should be directed to Mr. J. W. McBurney, Secretary of Committee C-3 on Brick, U. S. Bureau of Standards, Washington, D. C.

[2] See p. 842.

[3] 1927 Book of A.S.T.M. Standards, Part II. Criticisms of this revision are solicited and should be directed to Mr. E. S. Rankin, Secretary of Committee C-4 on Clay and Cement-Concrete Pipe, Bureau of Sewers, City Hall, Newark, N. J.

[4] 1927 Book of A.S.T.M. Standards, Part II. Criticisms of this revision are solicited and should be directed to Mr. H. D. Foster, Secretary of Committee C-10 on Hollow Masonry Building Units, Engineering Experiment Station, Ohio State University, Columbus, Ohio.

2. (*a*) According to the results of physical tests, tile shall be classified as Hard, Medium and Soft on the basis of the following strength and absorption requirements, both of which must be met for a given class:

Class	Absorption, per cent		Compressive Strength Based on Gross Area, lb. per sq. in.			
			End Construction		Side Construction	
	Mean of 5 Tests	Individual Maximum	Mean of 5 Tests	Individual Minimum	Mean of 5 Tests	Individual Minimum
Hard	12 or less	15	2000 or more	1400	1000 or more	700
Medium	16 or less	19	1400 or more	1000	700 or more	500
Soft	25 or less	28	1000 or more	700	500 or more	350

to read as follows:

2. (*a*) According to the results of the physical tests, tile shall be classified as Hard, Medium and Soft on the basis of the following strength and absorption requirements, the class of any lot being determined by the requirement which gives it the lowest rating:

Class	Absorption, per cent			Compressive Strength Based on Gross Area, lb. per sq. in.			
				End Construction		Side Construction	
	Mean of 5 Tests	Individual Maximum	Individual Minimum	Mean of 5 Tests	Individual Minimum	Mean of 5 Tests	Individual Maximum
Hard	6 to 12	15	5	2000 or more	1400	1000 or more	700
Medium	12 to 16	19	5	1400 or more	1000	700 or more	500
Soft	16 to 25	28	5	1000 or more	700	500 or more	350

Section 3 (a).—It is recommended that the 2-cell 8 by 5 by 12-in. unit weighing 16 lb. and the 6-cell 12 by 12 by 12-in. unit weighing 48 lb. be eliminated from the table of weights.

STANDARD SPECIFICATIONS AND TESTS FOR HOLLOW BURNED-CLAY FLOOR TILE

(SERIAL DESIGNATION: C 57 – 27)[1]

Section 2 (a).—Change the wording and the absorption requirements of this section from their present form: namely,

2. (*a*) According to the results of physical tests, tile shall be classified as Hard, Medium and Soft on the basis of the following strength and absorption requirements, both of which must be met for a given class:

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[1] 1927 Book of A.S.T.M. Standards, Part II. Criticisms of this revision are solicited and should be directed to Mr. H. D. Foster, Secretary of Committee C-10 on Hollow Masonry Building Units, Engineering Experiment Station, Ohio State University, Columbus, Ohio.

Class	Absorption, per cent		Compressive Strength Based on Net Area, lb. per sq. in.			
			End Construction		Side Construction	
	Mean of 5 Tests	Individual Maximum	Mean of 5 Tests	Individual Minimum	Mean of 5 Tests	Individual Minimum
Hard....................	12 or less	15	4600 or more	3000	2400 or more	1700
Medium..................	16 or less	19	3200 or more	2250	1600 or more	1100
Soft.....................	25 or less	28	2000 or more	1400	1200 or more	850

to read as follows:

2. (*a*) According to the results of the physical tests, tile shall be classified as Hard, Medium and Soft on the basis of the following strength and absorption requirements, the class of any lot being determined by the requirement which gives it the lowest rating:

Class	Absorption, per cent			Compressive Strength Based on Net Area, lb. per sq. in.			
				End Construction		Side Construction	
	Mean of 5 Tests	Individual Maximum	Individual Minimum	Mean of 5 Tests	Individual Minimum	Mean of 5 Tests	Individual Minimum
Hard............	6 to 12	15	5	4600 or more	3000	2400 or more	1700
Medium.........	12 to 16	19	5	3200 or more	2250	1600 or more	1100
Soft	16 to 25	25	5	2000 or more	1400	1200 or more	850

STANDARD DEFINITIONS OF TERMS RELATING TO THE GYPSUM INDUSTRY

(SERIAL DESIGNATION: C 11 – 28)[1]

Several definitions of terms published under the title "Tentative Definitions of Terms Relating to the Gypsum Industry (C 11 – 28 T)"[2] are intended to be added to the present standard definitions.

STANDARD DEFINITION OF THE TERM SAND

(SERIAL DESIGNATION: C 58 – 28)[3]

The Tentative Definition of the Term Aggregate (C 58 – 28 T)[4] is intended to be included, when adopted, with the present Standard Definition of the Term Sand.

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[1] 1928 Supplement to Book of A.S.T.M. Standards. Criticisms of this revision are solicited and should be directed to Mr. H. J. Schweim, Secretary of Committee C-11 on Gypsum, United States Gypsum Co., 300 W. Adams St., Chicago, Ill.

[2] See p. 821.

[3] 1928 Supplement to Book of A.S.T.M. Standards. Criticisms of this revision are solicited and should be directed to Mr. L. R. Ferguson, Secretary of the Sub-Committee on Definition of Sand and Aggregate of Committee E-8 on Nomenclature and Definitions, Texas Portland Cement Co., 1401 Santa Fe Building, Dallas, Tex.

[4] See p. 835.

STANDARD DEFINITIONS OF TERMS RELATING TO REFRACTORIES

(SERIAL DESIGNATION: C 71 – 28)[1]

Several definitions of terms published under the title "Tentative Definitions of Terms Relating to Refractories (C 71 – 28 T)"[2] are intended to be added to the present standard definitions.

D. MISCELLANEOUS MATERIALS

STANDARD SPECIFICATIONS FOR BROKEN SLAG FOR WATERBOUND BASE AND WEARING COURSE

(SERIAL DESIGNATION: D 65 – 23)[3]

Section 4.—Omit this section, reading as follows, renumbering the subsequent sections accordingly:

> 4. The percentage of wear shall be not more than 12.0 per cent.

Section 6.—Change the last line of this section to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

> [Retained on] *Passing* 2½-in. screen . . .not [less] *more* than [85] *15* per cent.

Section 7 (b).—Omit this paragraph which refers to the method for determining the percentage of wear.

STANDARD SPECIFICATIONS FOR SHOVEL-RUN OR CRUSHER-RUN BROKEN SLAG FOR WATERBOUND BASE

(SERIAL DESIGNATION: D 66 – 23)[3]

Section 4.—Omit this section, reading as follows, renumbering the subsequent sections accordingly:

> 4. The percentage of wear shall be not more than 15.0 per cent.

Section 6 (b).—Omit this paragraph which refers to the method for determining the percentage of wear.

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[1] 1928 Supplement to Book of A.S.T.M. Standards. Criticisms of this revision are solicited and should be directed to Mr. L. J. Trostel, Secretary of Committee C-8 on Refractories, General Refractories Co. Laboratories, P.O. Box 935, Baltimore, Md.

[2] See p. 858.

[3] 1927 Book of A.S.T.M. Standards, Part II. Criticisms of this revision are solicited and should be directed to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 441 Lexington Ave., New York City.

STANDARD SPECIFICATIONS FOR RUBBER PUMP VALVES

(SERIAL DESIGNATION: D 151 – 23)[1]

Section 4 (c).—Eliminate reference to reclaimed rubber.

STANDARD METHOD OF TEST FOR COARSE PARTICLES IN PAINT PIGMENTS

(SERIAL DESIGNATION: D 185 – 26)[2]

A revision in the form of separate tentative methods of test entitled "Methods of Test for Coarse Particles in Dry Pigments and Coarse Particles and Skins in Mixtures of Pigments and Vehicles (D 185 – 28 T)[3] is intended to replace when adopted the present standard method.

STANDARD METHODS OF ROUTINE ANALYSIS OF TITANIUM PIGMENTS

(SERIAL DESIGNATION: D 186 – 27)[2]

Change the central heading of Section 3 from "Color Strength" to read "Tinting Strength."

Add a new Section 10 to read as follows, renumbering the present Sections 10, 11 and 12 to Sections 11, 12 and 13, respectively:

CALCIUM SULFATE

(In the case of Titanium-Calcium Pigments)

10. Transfer 0.5 g. of the pigment to a 250-cc. beaker, add 25 cc. of HCl (1:1), cover with a watch-glass, and boil several minutes. Dilute to 150 cc. with water, heat to boiling, wash off the cover glass, filter through a 9-cm. filter paper, and wash the paper and residue with hot 1-per-cent HCl (prepared by mixing 10 cc. of HCl (sp. gr. 1.19) with 990 cc. of water) until the washings show no calcium when tested with NH_4OH and $(NH_4)_2C_2O_4$. To the filtrate, add 2 drops of concentrated HNO_3 and boil to insure oxidation of the iron. Add NH_4OH until slightly alkaline, and heat to boiling. Then without filtering, add an excess (30 to 35 cc.) of a hot saturated solution of $(NH_4)_2C_2O_4$, stir, and continue the boiling until the precipitate becomes granular. Let stand on a steam bath for one hour, and filter through a 9-cm. filter paper. Wash the beaker and filter with boiling-hot water until 10 cc. of the washings are not decolorized in 2 to 3 minutes after adding 0.5 cc. of H_2SO_4, heating to about 70° C., and adding 2 drops of 0.1 N $KMnO_4$ solution. Place the beaker in which precipitation was made under the funnel, pierce the apex of the filter

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[1] 1927 Book of A.S.T.M. Standards, Part II. Criticisms of this revision are solicited and should be directed to Mr. Arthur W. Carpenter, Secretary of Committee D-11 on Rubber Products, The B. F. Goodrich Co., Akron, Ohio.

[2] 1927 Book of A.S.T.M. Standards, Part II. Criticisms of this revision are solicited and should be directed to Mr. R. L. Hallett, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 105 York St., Brooklyn, N. Y.

[3] See p. 874.

paper with a stirring rod and wash the precipitate into the beaker with a jet of hot water; pour 30 cc. of warm dilute H_2SO_4 (1:3) through the filter so that the acid comes in contact with all of the paper, and wash the funnel and filter thoroughly with hot water. Dilute to about 250 cc. with water, heat to about 90° C., and titrate at once with 0.1 *N* $KMnO_4$ solution to a faint pink color that does not disappear in 2 to 3 minutes (the temperature of the solution should not be below 60° C. when the end point is reached). Calculate the total calcium to percentage of $CaSO_4$ (1 cc. of 0.1 *N* $KMnO_4$ is equivalent to 0.0068 g. $CaSO_4$ or 0.0028 g. CaO. The Fe value of $KMnO_4 \times 0.502 =$ CaO value).

STANDARD METHODS OF TESTING SHELLAC

(SERIAL DESIGNATION: D 29 – 25)[1]

Section 1.—Add to the present note to this section a new paragraph to read as follows:

NOTE.—An 8-in. glass condenser may be substituted for the metal condenser, the stem perforated with 2 holes, from which the siphon is suspended by wire. The condenser is fitted to the neck of the flask (same size and type as described by the method) with a cork stopper. A free flow of cooling water should be maintained during extractions. The use of an Allihin condenser for extractions (with bulbs) is recommended.

Section 3.—Change the second paragraph of this section to read as follows by the addition of the italicized words and the omission of those in brackets:

Dry in an air bath at 105° C., transfer to a glass-stoppered weighing bottle, cool and weigh. Dry to constant weight. A number of cartridges can be prepared and kept in glass-stoppered weighing bottles until wanted. Now weigh 5 g. of the lac in a [100] *200*-cc. *tall* beaker and dissolve in [75] *100–120* cc. of boiling [95-per-cent] alcohol, [by immersing] *immerse* the beaker in a hot water bath, [until] *in order to be certain* all the shellac is dissolved and the wax is in solution. *The alcohol and shellac mixture should be brought to a brisk boil and maintained for 30 minutes at or near the boiling point.* Transfer this solution quickly into the weighed extraction cartridge, previously wet with hot alcohol, putting the cartridge into a carbon filter tube of suitable size supported in a hot water bath (Fig. 2), the outlet tube extending through the bottom of the bath allowing the escape of the filtrate. Wash all the residue from the beaker into the cartridge with hot 95-per-cent alcohol. Put the cartridge in the extraction apparatus (Fig. 1), and extract [for exactly] *to constant weight, in no case less than* one hour.

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[1] 1927 Book of A.S.T.M. Standards, Part II. Criticisms of this revision are solicited and should be directed to Mr. R. L. Hallett, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 105 York St., Brooklyn, N. Y.

STANDARD METHODS OF LABORATORY SAMPLING AND ANALYSIS OF COAL AND COKE

(SERIAL DESIGNATION: D 271 - 27)[1]

A revision in the form of separate tentative methods entitled "Methods for the Determination of Sulfur in Coal and Coke by the Bomb-Washing and Sodium Peroxide Fusion Methods (D 271 - 27 T)"[2] is intended to be added to the present standard methods.

A revision is also recommended in the methods for determination of phosphorus in the ash of coal and coke. Replace the present Sections 21 and 22 with the following:

DETERMINATION OF PHOSPHORUS IN ASH

(For Coal and Coke)

Solution Required

21. *Solution Required.—Molybdate Solution.*—Dissolve 65 g. of molybdic acid (85-per-cent) in a mixture of 143 cc. of NH_4OH (sp. gr. 0.90) and 142 cc. of water. Add this solution slowly, with constant stirring, to 715 cc. of HNO_3 (sp. gr. 1.20). If the solution is cloudy, add two drops of a solution of ammonium phosphate (20-per-cent) and allow the precipitate which forms to settle. Filter the solution into bottles and, if necessary, re-filter just before using. If the molybdic acid used is 100-per-cent, 56 g. should be taken instead of 65 g.

Method

Method No. 1, for all Cases:

22. (*a*) *Determination of Phosphorus in Ash.*—Add to the ash from a 5-g. sample, in a platinum crucible, 10 cc. of concentrated HNO_3 and 3 to 5 cc. of HF. Evaporate the liquid and fuse the residue with 3 g. of Na_2CO_3. If unburned carbon is present, mix 0.2 g. of $NaNO_3$ with the carbonate. Leach the melt with water and filter the solution. Ignite the residue, fuse with Na_2CO_3 alone, leach the melt with water and filter the solution. Just acidify with HNO_3 the combined filtrate held in a flask, add 3 to 5 cc. of concentrated HNO_3 in excess, and concentrate to a volume of 100 cc. Add 6 g. of NH_4NO_3, bring the temperature of the solution to 80° C., add 50 cc. of molybdate solution and shake the flask for 10 minutes. When the precipitate has settled, filter and wash the precipitate, until free from acid, with a KNO_3 solution (2-per-cent). Place the filter paper with the precipitate in the flask, add 25 cc. of recently boiled distilled water, and macerate the filter paper with a glass stirring rod. Add a measured excess of standard NaOH solution and agitate the solution to completely dissolve the precipitate. Add 3 drops of phenolphthalein solution as an indicator and titrate the excess NaOH with a standard HNO_3 solution. The alkali solution may well be made equal to 0.00025 g. of phosphorus per cubic centimeter, or 0.005 per cent for a 5-g. sample. Such a solution would be 0.926 of 0.2 *N*.[a]

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[a] Ullman and Buch, ***Chemical Engineer***, Vol. 10, p. 130 (1909).

[1] 1927 Book of A.S.T.M. Standards, Part II. Criticisms of this revision are solicited and should be directed to Mr. W. A. Selvig, Secretary of Committee D-5 on Coal and Coke, U. S. Bureau of Mines, 4800 Forbes St., Pittsburgh, Pa.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 959 (1927); also 1928 Book of A.S.T.M. Tentative Standards, p. 551.

NOTE.—The advantage of the use of HF in the initial attack of the ash lies in the resulting removal of silica. Fusion with alkali carbonate is necessary for the elimination of titanium, which if present and not removed will contaminate the phospho-molybdate and is said to sometimes retard its precipitation.

Method No. 2, when Titanium is Low:

(*b*) When titanium is so low as to offer no objection, decompose the ash as described in Paragraph (*a*), *Method No. 1*, but carry the evaporation only to a volume of about 5 cc. Dilute the solution with water to 30 cc., boil and filter into a flask. If the washings are turbid pass them again through the filter. Ignite the residue in a platinum crucible, fuse with a little Na_2CO_3, dissolve the melt in HNO_3 and add the solution, if clear, to the main one. If not clear, filter. The fusion of the residue may be dispensed with in routine work on a given coal or coke if it is certain that the residue is free from phosphorus. Add NH_4OH until a slight precipitate ensues. Add concentrated HNO_3 to just dissolve the precipitate, then add 3 to 5 cc. of the acid in excess. Heat the solution, which should have a volume of about 100 cc., to 80° C. and add 50 cc. of molybdate solution. Shake the flask for 10 minutes, filter, and determine the phosphorus as described in Paragraph (*a*), *Method No. 1*.

STANDARD METHODS OF TESTING MOLDED INSULATING MATERIALS

(SERIAL DESIGNATION: D 48 – 27)[1]

Section 2.—Change from its present form: namely,

2. Any standard testing machine may be used provided the error in the loading range does not exceed 1 per cent. Special clips (see Fig. 1) of hardened steel shall be used, hung from links held in the jaws of the machine, so that the pull is central at all times, to avoid any transverse strain.

to read as follows:

2. Any standard testing machine may be used provided it is accurate to within 1 per cent of the lowest load to be applied. Special specimen holders of steel, as shown by Fig. 1 (*a*), shall be used. The specimen holders shall be attached to the heads of the machine by links held so that the pull is central to avoid any transverse strain.

Section 3.—Change from its present form: namely,

3. The standard test specimen shown in Fig. 1 shall be used for the tension tests. It shall be molded to the dimensions shown in Fig. 1.

to read as follows:

3. For hot-molded materials and for plastic cold-molded materials (see Note 1), the test specimen shall be molded to the form and dimensions shown in Fig. 1 (*b*).

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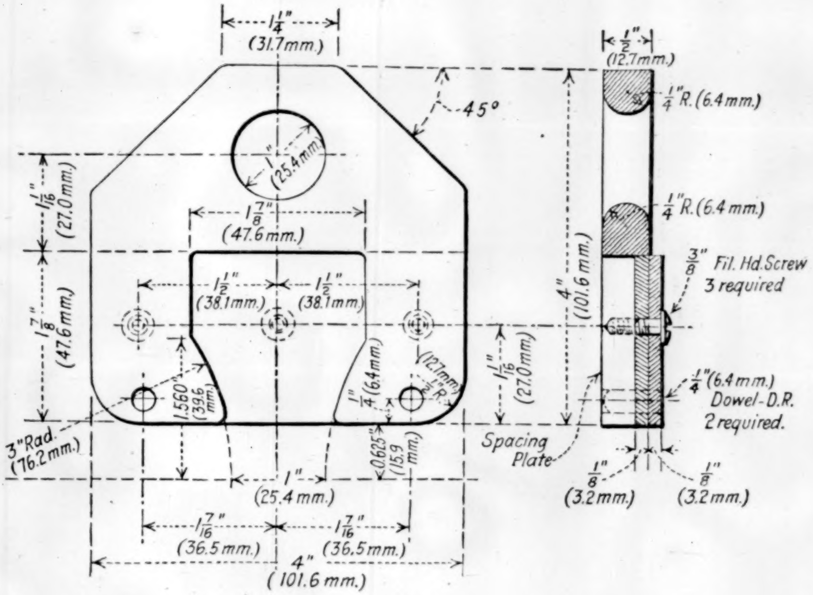
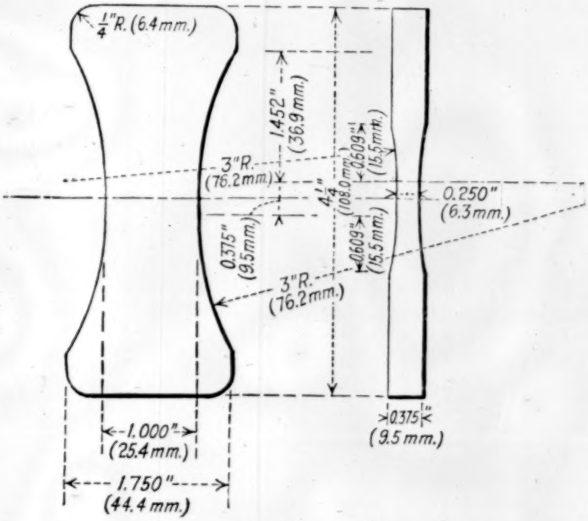
[1] 1927 Book of A.S.T.M. Standards, Part II. Criticisms of this revision are solicited and should be directed to Mr. T. S. Taylor, Secretary of Committee D-9 on Electrical Insulating Materials, Bakelite Corporation, 230 Grove St., Bloomfield, N. J.


1 1/4" (31.7mm.)
45°
1" (25.4mm.)
1 1/16" (27.0mm.)
1 7/8" (47.6mm.)
1 7/8" (47.6mm.)
1 1/2" (38.1mm.)
1 1/2" (38.1mm.)
1.560" (39.6 mm.)
1/4" (6.4mm.)
1/2" (12.7mm.) R.
1 1/16" (27.0mm.)
0.625" (15.9 mm.)
3" Rad. (76.2mm.)
1" (25.4mm.)
1 7/16" (36.5mm.)
1 7/16" (36.5mm.)
4" (101.6 mm.)
4" (101.6 mm.)
1/2" (12.7mm.)
1/4" R. (6.4mm.)
1/4" R. (6.4mm.)
3/8" Fil. Hd. Screw 3 required
1/4" (6.4mm.) Dowel-D.R. 2 required.
Spacing Plate
1/8" (3.2mm.)
1/8" (3.2mm.)

(a) Specimen holder.


1/4" R. (6.4mm.)
1.452" (36.9mm.)
3" R. (76.2mm.)
4 1/4" (108.0mm.)
0.609" (15.5mm.)
0.609" (15.5mm.)
0.250" (6.3mm.)
0.375" (9.5mm.)
3" R. (76.2mm.)
1.000" (25.4mm.)
1.750" (44.4mm.)
0.375" (9.5 mm.)

(b) Tension test specimen.

FIG. 1.—Tension Test Specimen and Holder.

NOTE 1.—Due to wide differences in molding characteristics, the specimen suited to hot-molded and plastic cold-molded materials is unsuited to the non-plastic inorganic cold-molded materials. A specimen suitable for these latter compounds is now under consideration.

Section 4 (b).—Omit the last sentence of this section, reading as follows:

Measurements may be taken at intervals during the test to show the elongation of the specimen when required for elastic materials.

Section 5.—Change Paragraph (*b*) to read as follows by the addition of the italicized words:

(*b*) The thickness *and width* of each specimen in inches or millimeters as measured by a micrometer at the center of the specimen, that is, the point of minimum section.

Change Paragraph (*d*) from its present form: namely,

(*d*) The character of the material tested, with description of how it acts under stress.

to read as follows:

(*d*) The character of the material tested, with a description of the fracture and its location with respect to the middle point of the specimen.

Change Paragraph (*e*) to read as follows by the addition of the italicized words and the omission of the word in brackets:

(*e*) The speed in inches or millimeters per minute at which the [jaws] *head of the testing machine* traveled during the test.

Figure 1.—Replace the present figure showing the tension test specimen with a new figure conforming to the accompanying Figs. 1 (*a*) and (*b*).

Section 15.—Change from its present form: namely,

15. The test specimen shall be molded to the dimensions shown in Fig. 4. The mold shall be hardened and ground to these dimensions. If the material cannot be molded to the full height shown, the height may be reduced to 1¼ in. (31.8 mm.).

For materials having a puncture value higher than 300 volts per mil, the thickness of the bottom of the specimen may be reduced to 0.098 in. (2.5 mm.). It should be noted, however, that the apparent dielectric strength in volts per mil may be increased as much as 50 per cent when the thickness of the bottom of the specimen is so reduced.

to read as follows:

15. The test specimen shall be molded in the form of a disk 4 in. (10.16 cm.) in diameter which should be ⅛ in. (3.18 mm.) in thickness for hot-molded materials and ¼ in. (6.35 mm.) in thickness for cold-molded materials.

Section 16.—Change Paragraph (*a*) from its present form: namely,

(*a*) Voltage shall be applied to the test specimen by floating the specimen on mercury and placing a pool of mercury about ⅛ in. (3 mm.) deep inside the specimen.

It is recommended that all tests be made in air, but whenever it is impossible to puncture the specimen in air without arcing over the edge, it shall be immersed in high-grade transformer oil. On specimens which require a very high voltage to puncture, it may be necessary to put a glass tube or shield over the wire leading to the mercury on the inside of the specimen in order to prevent breakdown over the surface of the oil between terminals. The testing voltage shall be raised at a constant rate of approximately one thousand volts per second until puncture occurs.

to read as follows:

(*a*) Voltage shall be applied to the test specimen by means of two flat electrodes 1 in. in diameter with edges rounded to a radius of ⅛ in. These electrodes shall be placed directly opposite each other at the center of the specimen.

It is recommended that all tests on hot-molded materials be made under oil and tests on cold-molded materials in air. Testing voltage shall be raised at a constant rate of approximately 1000 volts per second until a puncture occurs.

Omit Paragraph (*c*) reading as follows:

(*c*) The results from specimens where puncture takes place up on the side of the specimen instead of through the bottom shall be discarded. Experience shows that very plastic materials which flow easily in the mold always puncture through the bottom, while materials which do not mold readily will often puncture through the side walls of the specimen at some distance up from the bottom.

Section 17 (*a*).—Change from its present form: namely,

(*a*) The thickness of the bottom of each specimen measured with a micrometer in the direction perpendicular to the bottom surface, and also the thickness at the point of puncture, regardless of the path taken by the discharge. The thickness of each specimen shall be given in mils or in millimeters.

to read as follows:

(*a*) The thickness of each specimen shall be given in mils or millimeters.

Figure 4.—Omit this figure.

STANDARD METHODS OF TESTING RUBBER PRODUCTS

(SERIAL DESIGNATION: D 15 – 24)[1]

A revision in the form of separate tentative methods of chemical analysis entitled "Methods of Chemical Analysis of Rubber Products (D 297 – 28 T)"[2] is intended to replace, when adopted, Sections 1 to 47 of the present standard methods.

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[1] 1927 Book of A.S.T.M. Standards, Part II. Criticisms of this revision are solicited and should be directed to Mr. Arthur W. Carpenter, Secretary of Committee D-11 on Rubber Products, The B. F. Goodrich Co., Akron, Ohio.

[2] See p. 1072.

STANDARD DEFINITIONS OF TERMS RELATING TO PAINT SPECIFICATIONS

(SERIAL DESIGNATION: D 16 - 24)[1]

Add the following three new definitions of terms:

Screen (*Sieve*).—A plate or sheet or a woven cloth, or other device, with regularly spaced apertures of uniform size, mounted in a suitable frame or holder, for use in separating material according to size.

NOTE 1.—The shape and spacing of apertures, size of wires or threads, thickness of plate or sheet, allowable variations and similar properties should be taken care of in specifications.

NOTE 2.—In mechanical analysis testing work, when not otherwise specified, the term "sieve" shall apply to an apparatus in which the apertures are rectangular, and the term "screen" shall apply to an apparatus in which the apertures are circular.

Toughness.—That quality of a material which may be measured by the maximum impact which it will withstand without rupture.

Elasticity.—In the case of paint or varnish, that property which allows a film to follow, without rupture, changes in the extent and form of the surface to which it is applied.

STANDARD DEFINITIONS OF TERMS RELATING TO TEXTILE MATERIALS

(SERIAL DESIGNATION: D 123 - 27)[2]

Several definitions of terms published under the title "Tentative Definitions of Terms Relating to Textile Materials (D 123 - 28 T)"[3] are intended to be added, when adopted, to the present standard definitions.

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[1] 1927 Book of A.S.T.M. Standards, Part II. Criticisms of this revision are solicited and should be directed to Mr. R. L. Hallett, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 105 York St., Brooklyn, N. Y.

[2] 1927 Book of A.S.T.M. Standards, Part II. Criticisms of this revision are solicited and should be directed to Mr. J. E. Skane, Secretary of Committee D-13 on Textile Materials, Manhattan Rubber Manufacturing Co., Passaic N. J.

[3] See p. 1105.

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